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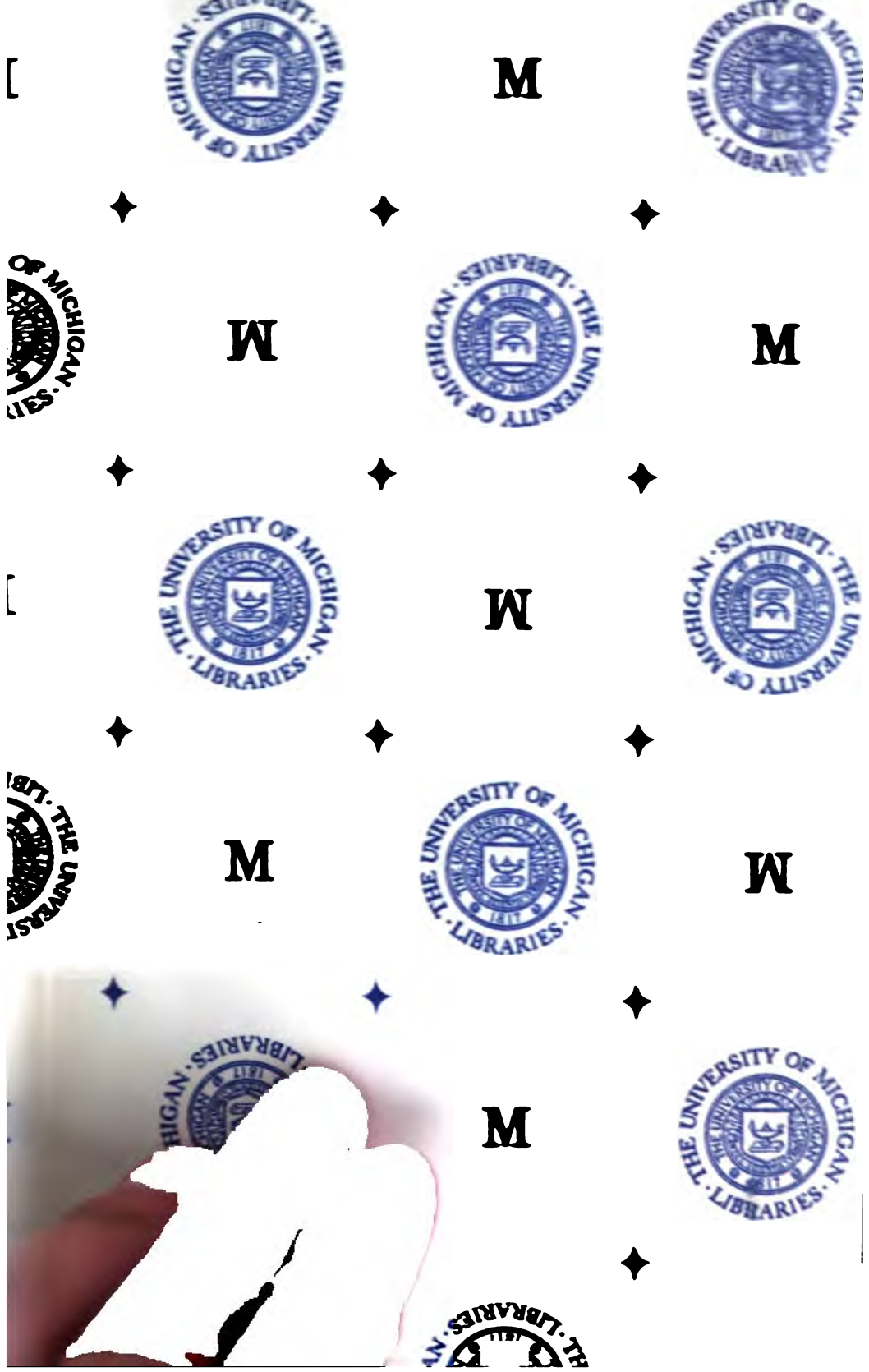
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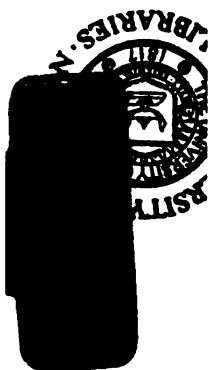


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JOHN A. REID.

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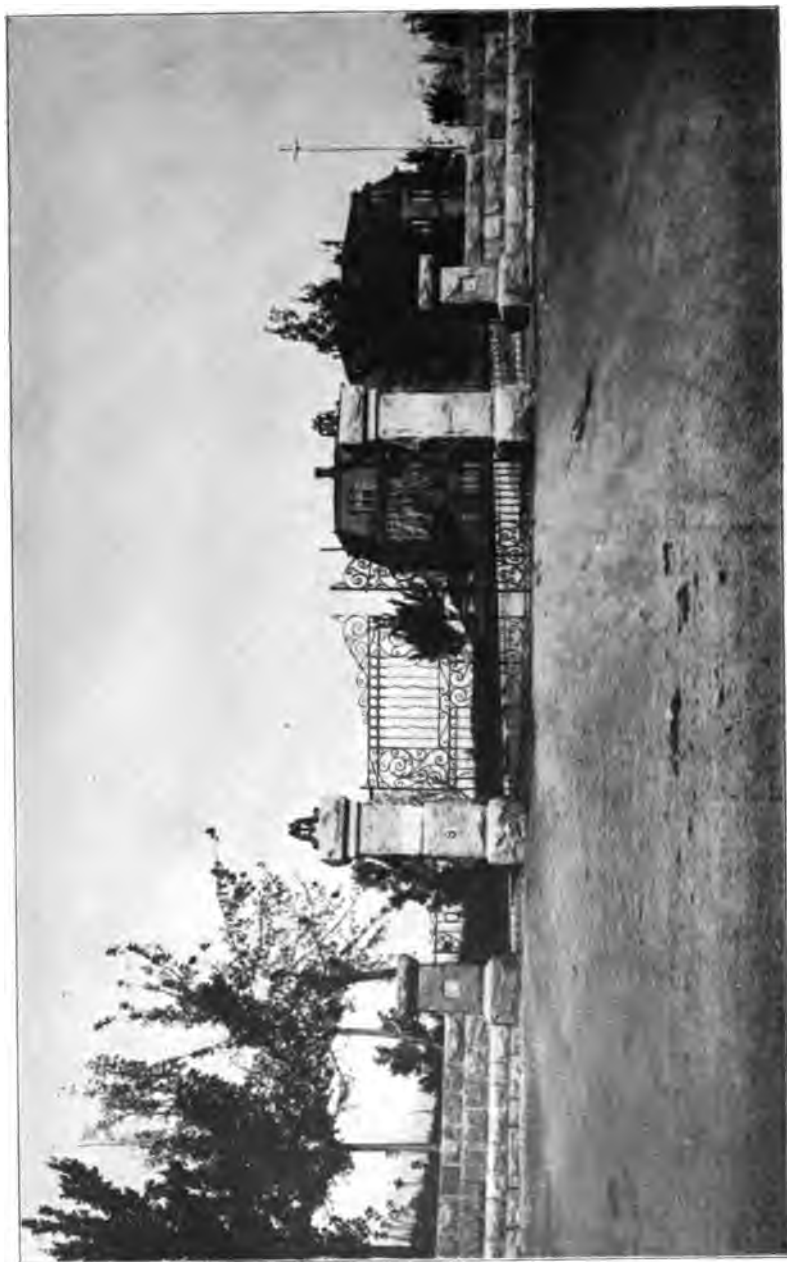
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INTRODUCTION.

CHAPTER I.

The statement that the West is undeveloped is undeniably true. It is doubly true of the State of Nevada. Little has been done to develop her natural resources; little is known of the boundless wealth of her mountains and valleys. Yet Nevada is on the eve of a great awakening; with the advent of irrigation thousands of acres of fertile land, now desert like, will be made to yield an abundance of the fruits of the field, and will support a large population. As the community increases in numbers, a demand will arise for all modern improvements, among which two of the most important are, permanent buildings and good roads. It is needless to state that both of these are made possible by the use of stone; stone for erecting substantial, handsome structures, and stone for the betterment of the highways, which are so important to the healthy life of a growing community. It is not needless, however, to state that the principle underlying the choice and use of stone for the above purposes are little understood. Moreover, were these principles understood, little is known of the various rocks in the state available at present. The purpose of this preliminary report, then, is as follows: First, to present the main principles governing the selection and use of building stones and road metal; second, to describe briefly the stones now in use, or that can easily be used, in Nevada, with their location and availability; and third, to attempt to arouse a larger interest in a subject of such vast importance to a healthy commonwealth,

We in the West are prone to build for the day only; tomorrow is allowed to care for itself. This is undoubtedly cheaper at any particular time, but is far dearer in the end. The scale of any civilization may be told from its architecture; the stability of that civilization is shown by the materials used in the architecture. But we are learning to build, not for mere decades, but for centuries of use, and to do this we must use stone. The first cost may be high, but the ultimate expense is low. The result of this is to be seen now in many places. Not only are stone buildings more common, but also the use of stone is seen in bridges, culverts, roads, curbing, and in many other ways too numerous to mention. In a rapidly growing state like Nevada the importance of these considerations cannot easily be overestimated, yet that importance is little realized. The frontier town is one of tents

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and temporary light wooden buildings. Everything is done with the greatest haste, and calculated to bring in the largest returns for the least expenditure. Every western town has gone through such a period in its growth. After this first newness has worn off a bit, more stable conditions obtain, and almost imperceptibly more solid and substantial structures appear, to take the place of the first flimsy ones. In mountainous regions such as Nevada, men have turned instinctively to the rocks in the hills for building materials. As a consequence nearly all of the towns of the state show one or more stone buildings, while in the larger ones, as Reno and Virginia City, brick is common also as a material of construction. Yet even with brick structures, stone is required for cornices, arches, and similar uses. The people need to know something about the proper and improper use of these materials, which of course, is the reason for the writing of this report.

The nature of this subject is more complex than appears on casual inspection. Fundamental principles of three separate sciences all play an essential part; the subject is built upon geology, physics and chemistry. The practical man may believe that he has no time for such considerations, yet the simplest rule of thumb method, if it be right, is founded upon true scientific principles. No man in this advancing age of competition can afford to be ignorant of those things which vitally concern him and his business. Every citizen, directly or indirectly, is concerned with the erection of public buildings, private buildings, and county and city highways. Hampered by lack of facilities for detailed work, a full report on the subject is impossible for some time, yet the time is ripe for a little knowledge to be distributed about these matters.

The chief uses of rock are as follows, in order of their relative importance. First, the largest amount of stone is used in the construction of buildings, under conditions already mentioned. Second, much of the finest grade of stone is used for monumental and ornamental work. It is not right, nor is it necessary, that nearly all of our rocks for such uses come from outside localities. Third, the importance of crushed rock for the construction of roads is well known. Fourth, in the larger towns and cities, stone curbing is imperative on the graded streets. Fifth, the use of cut stone for bridges and culverts, especially by the railroads, is growing constantly. Sixth, much cut rock is used for sidewalks and by the railroads. Sixth, much cut rock is used for sidewalks and tiling in the most approved buildings. Besides these, there are many lesser uses, such as the construction of piers, break-waters, dams, retaining walls, with such small uses as hitching posts,

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steps, mounting blocks, and the like. And it is worth noting that this list is constantly increasing.

The text will be divided into five succeeding chapters; a short chapter on the nature of the various rocks, with their classification; a second chapter devoted to the qualities of building stones, good and bad; a third devoted to an account and description of the building stones of Nevada; fourth, a brief chapter on road metal; and lastly a conclusion.

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CHAPTER II.

ROCKS: THEIR NATURE AND CLASSIFICATION.

To the average man, any rock is either a granite, a porphyry, a sandstone, or a slate; these terms are all embracing. Were it not that this loose use of terms is productive of actual loss in construction, by causing a misunderstanding of the characteristics of a stone, with consequent misuse, this chapter would be superfluous. But when such a broad error is made as the use of a partially decomposed volcanic rock, an andesite, under the belief that it was a sandstone, which is a rock not often subject to decomposition, at least in the better grades, the writer feels it necessary to present in some detail the various types of rocks found in the earth.

The first question naturally arising is this: What is a rock? A proper definition is as follows: A rock is any material making up an integral part of the earth; that is, any substance which exists in large enough amount to be considered as constituting an essential portion of the globe. This definition, however, though a strictly scientific one, seems rather too broad for our present needs, for by it the soils, water, ice, and all the soft as well as hard materials, are classified under one great head. Here we are only to consider the hard rocks, or stones, and have use for no others. The definition should be kept in mind, nevertheless, for there is no well defined line between a sand and a sandstone, a clay and a shale, or a gravel and a conglomerate.

The rocks of the earth are divided into three grand classes, as follows:

- I. *The Igneous or Massive Rocks.*
- II. *The Atmospheric, or Stratified Rocks.*
- III. *The Metamorphic, or Changed Rocks.*

Let it be understood that in the following remarks under classification, the chief aim has been to present, to the general reader and practical worker, a mere outline showing how rocks are grouped. It is utterly impossible to describe a rock without some knowledge of minerals on the part of the reader, hence the following brief attempts at describing each rock must be understood as incomplete and greatly limited in scope. It is hoped the descriptions may convey some ideas to the practical man as an aid to his work, as well as act as references for the rocks to be later described.



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THE IGNEOUS ROCKS.

The Igneous Rocks are those made by the agency of heat, that is, have cooled from a molten condition. They are also called the massive rocks, because of their structure, which is, broadly speaking, the same in all directions. Also the term eruptive is applied to them, because of their origin as eruptive molten masses. These rocks occur in several different ways, as follows:

1. *Batholites*, or those immense masses of igneous rocks, as granites, which form the axes of our greatest mountain ranges. They are characterized by their great size, their evident position beneath other rocks, and the fact that as far as is known they descend to the deep interior mass of the earth.

2. *Laccolites*, or those dome shaped rock masses which have been intruded between layers, or strata, of other rocks, lifting them up like immense blisters. They differ from batholites mainly in the fact that they rest upon other rocks and are smaller in size.

3. *Sheets or Sills*, or those occurrences of igneous rocks which lie between other rocks as mere sheets, or on top of them. They differ from laccolites in that they are everywhere of about the same thickness and have caused no doming of superincumbent rocks. They may have been intruded between other rocks, or poured out upon the surface as lava flows, and are usually more nearly horizontal than vertical.

4. *Dykes*, or intrusive masses filling fissures, much as do mineral veins. These dykes usually cut across other rocks, are of great length on the surface compared with their width, and descending to unknown depths. They are usually more nearly vertical than horizontal.

5. *Irregular Masses*, such as volcanic necks, which are merely the hardened lava in the throat or pipe of an extinct volcano, standing up as a more or less conical mass after the wearing away of the soft cone. Also, we have very irregular bodies of igneous rocks of various sizes and shapes which are intruded into overlying rocks. To these, for lack of a better name, the term "stock" is applied. As a grand division, the igneous rocks are those from which all others are derived.

CLASSIFICATION.

To handle this subject of rock classification from a popular

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standpoint is a delicate task. The principles underlying it can only be partly stated, for obvious reasons. A knowledge of mineralogy cannot be expected, and all that will be done in what follows is to attempt to render intelligible in the simplest possible manner, the main features of the subject. A working knowledge of the simpler minerals, as quartz, feldspar and mica, will be assumed.

The igneous rocks are classified along two lines. First, chemically, they range from acid to basic, with all gradations between. This variation results in the formation of different minerals, so that the chemical rock types have different appearances. Secondly, these rocks are classified on a basis of what is called texture. Those which have cooled at great depths from a molten condition have done so slowly, with a result that they are thoroughly crystallized, often coarsely so. On the other hand, those which have cooled on the surface and hence quickly, are glassy, at times being a simple glass. The thoroughly crystalline, deep seated rocks are called *plutonic*, the glassy, surface ones are called *volcanic*. Those which have cooled and solidified a short way below the surface are often spoken of as dyke, trap, or intermediate rocks. In accordance with these two lines of difference, then all rocks which have solidified from a molten condition are classified. It will be noticed that there are, unfortunately, two kinds of intermediate rocks: those chemically intermediate and those occupying a middle position on the basis of crystalline texture. However, when an intermediate rock is mentioned, one of the latter kind will usually be meant, or a dyke rock. The meaning of the various textures may be looked at in this way. A granite, for instance, is the type of an acid plutonic rock. Melted and cooled rapidly it would form a glassy volcanic rock, and, of course, called a rhyolite. Melted and cooled more slowly, yet not so slowly as a deep seated rock loses its heat, an intermediate acid type, with some crystals showing, would result. This rock would be called a quartz-porphyr. A more basic plutonic rock, as a diorite, when similarly treated would yield a volcanic *andesite* and a dyke phase *porphyrite*. These facts are embodied in the following table, in which only the few main types are mentioned. The many varieties and sub-types made by the petrographer are not necessary in such a report as this.

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TABLE OF CLASSIFICATION.

COMPOSITION	TEXTURE		
	PLUTONIC	INTERMEDIATE	VOLCANIC
Acid	Granite	Quartz-Porphry	Rhyolite
Intermediate	Syenite	Porphyry	Trachyte
	Diorite	Porphyrite	Andesite
Basic	Gabbro	Diabase	Basalt
Ultrabasic	Peridotite	LIMBURGITE	

A peculiar fact to be noted about these rocks is this: Of the plutonic rocks the acid ones, the granites, are most common throughout the earth, while of the volcanic rocks the basic, the basalts, are best developed. Another fact is to be noted regarding the different names. For reasons not necessary to state here the names of the intermediate rocks, quartz-porphry, porphyry and porphyrite, are being dropped, and the volcanic terms used to cover them. For example, andesites and porphyrites are called merely andesites.

THE INDIVIDUAL ROCKS

PLUTONIC.

All wholly crystalline, often coarsely so.

1. *Granite*: The granite family consists of acid rocks, wholly crystalline with a coarse to medium fine grain, and of a grayish or reddish color. Free quartz, in colorless crystals, at times tinged bluish or reddish, is always present. Also a white or reddish feldspar, usually clouded with other whitish substances, and some dark mineral, as brown mica, are to be seen. In some rarer granites only a white mica, besides the quartz and feldspar, is present. The granites are the most easily determined of all the igneous rocks, and can be confused only with one other kind. The feldspar of a true granite contains potash, and is comparatively acid. A rock very similar to a granite, a diorite with free quartz, differs only in the nature of the feldspar, which contains, in place of potash, soda and lime, making it more basic. To the eye of any one but a trained observer, the two rocks appear precisely the same, showing colorless quartz, white feldspar and some dark mineral. This diorite with quartz is called a granite-diorite, grano-diorite, or quartz-diorite.

2. *Syenite*. The syenite family may be briefly character-

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ized as granites without quartz. They are comparatively rare rocks, especially in the western part of the United States. In color they vary about as do the granites, from shades of gray to pinkish or reddish tints. The minerals are simply feldspar and some dark colored ones, as mica or hornblende.

3. *Diorite*. Of this family the quartz bearing variety, grano-diorite, has already been mentioned. The other varieties are without quartz and more basic than syenites, and have about the same grain as the granites and syenites, though averaging a little finer. The fresh rocks are gray in color typically, but darker than the above mentioned types, and show a white feldspar with some dark mineral, usually hornblende.

4. *Gabbro*. The gabbro family is the most basic of the normal plutonic rocks, which are of complex nature. These rocks are often coarser in grain than any yet mentioned, the individual crystals at times being an inch or so in diameter. In general their color is grayish, often with a dark olive green tinge. Other colors are black, brown, green and in some varieties white. The minerals present are a white feldspar, often with a greenish stain, and some dark mineral which may be dark green, brown or black. Some types are wholly feldspar, and white in color. The gabbros are rare rocks, particularly in this western region.

5. *Peridotites*. These rocks are a peculiar family composed entirely of dark minerals. The feldspars are typically absent, hence the rocks are called ultra-basic, for the dark minerals are usually black, with sometimes a tinge of green. They alter as a rule to the common mineral and rock known as serpentine.

INTERMEDIATE ROCKS.

These rocks, with the exception of the diabases, show what is called porphyritic texture. As far as appearances are concerned, this texture causes the rocks to show well developed crystals of some mineral set in a paste of fine grained material which usually cannot be resolved into its component parts by the unaided eye. This fine grained paste is called the ground mass; the well formed crystals set therein are termed phenocrysts. To the naked eye the different kinds of these intermediate rocks are distinguished by the occurrence of certain minerals in well developed crystals and also by the color and general appearance of the ground mass.



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They are as follows:

1. *Quartz-porphyry*. In this rock are seen crystals of clear colorless quartz, with sometimes feldspar and mica, all set in a ground mass of various shades, from almost black, but sub-transparent, through shades of red, pink and grayish. This ground mass varies in grain, from that which looks like an exceedingly fine grained granite to apparently almost glassy. However, as with the granites, free quartz is characteristic. Where the ground mass is noticeably granite-like though very fine in grain, the rock is called a granite porphyry.

2. *Porphyry*. Often this rock is called an orthoclase porphyry or syenite porphyry, depending upon coarseness of grain. The relations between this rock and syenite is precisely that existing between quartz porphyry and granite. Also porphyry and quartz porphyry are connected in the same way that syenite and granite are. Free quartz is absent, and the minerals appearing as phenocrysts are feldspar, typically the potash variety, orthoclase, with often mica or hornblende. When the ground mass appears fine crystalline to the unaided eye the rock may be called a syenite porphyry. As a rule the rock looks much the same as quartz porphyry, differing in that free quartz is absent and replaced by white or glassy feldspar.

3. *Porphyrite*. These rocks are the chemical equals of the diorites, but having cooled near the surface, lack their crystalline texture. They are usually much darker rocks than the preceding, showing well developed crystals—phenocrysts—of typically a dark mineral, but sometimes a white feldspar, in a dark gray, dark green, or even black, ground mass. As with the first two types of intermediate rocks, when the ground mass appears finely crystalline we may have a diorite porphyry. These rocks often assume a reddish hue when weathered.

4. *Diabases*. These rocks are the equivalent of the gabbros, occurring typically as dykes and laccolites. They constitute the greatest body of dyke forming rocks known. They are seldom porphyritic, differing from the preceding but are wholly crystalline, appearing on casual observation like fine grained diorites. There are, however, some differences of note. As with the diorites they are composed of a light mineral and a dark one, but the dark one usually has a dark green tinge and a greasy luster seldom present in the black mineral of the diorites. Also, the white feldspar in the true diabases is seen to

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be in well formed crystals with the dark mineral crystallized around and between. The reverse is true with the other wholly crystalline rocks; the black mineral shows the best crystal form. with the white feldspar in the spaces between.

VOLCANIC ROCKS.

These rocks constitute the lavas, or surface flows of molten rock. In texture they range from porphyritic to glassy; chemically they cover the same range as the plutonic rocks, from acid to basic. The common term "obsidian" means a volcanic glass of any chemical constitution whatever. Being cooled lava flows they often show what are called flow or fluxion lines. Their varieties are below, and it is to be remembered that these names are now used to cover both volcanic and intermediate types of rocks.

1. *Rhyolite*. These rocks are the most acid of the lavas, corresponding chemically to the granites. In color they are usually various shades of white, gray, blue, pink or green, but are always of light tints except the obsidians, which may appear dark. When porphyritic, they look like quartz-porphyrries, into which they shade by insensible gradations, always showing free quartz. When no crystals of any kind are to be seen, yet if the rock is not all glass, their typical white or whitish color serves to distinguish them. The old term felsite is often given to these white varieties which are too fine grained to show any well formed crystals.

2. *Trachyte*. The trachytes are much like the rhyolites in appearance, but differ in showing no free quartz. The only minerals showing are typically white or glassy feldspar with sometimes a small amount of the darker varieties. They have usually a characteristic rough feel, hence the name *trachyte*, which means rough. Specifically, their color is often white, varying to shades of pinkish white or green. The whiteness is more pronounced than in the rhyolites because of the absence of glassy quartz. The trachyte obsidians, like the rhyolitic ones, are darker, often black in large fragments. The family as a whole is a rare one.

Andesite. This family of rocks is much darker than the two volcanic groups already mentioned. The color ranges from a fairly light gray to a black, a dark gray being an average hue. The well formed crystals—the phenocrysts—show both light and dark in color. Some andesites show black

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crystals in a light gray ground mass, while others show white feldspars in a dark gray or black ground mass. In some varieties the feldspars are glassy, resembling quartz on cursory inspection. Quartz does occur in one variety, known as dacite. This rock bears the same relation to an andesite that a quartz-diorite does to a diorite. At times an andesite shows no crystals to the unaided eye, when its color is nearly black, much like a basalt. A noteworthy fact is that these rocks tend to weather a dark red color, due to the iron oxide formed by atmospheric agencies.

4. *Basalt.* These common volcanic rocks are prevailingly black or nearly so. They show discernable crystals less often than the above types, and are usually finer grained and more homogeneous in appearance. However, in some common varieties small grains of a light greenish mineral appear on close inspection—the mineral olivine—and again, at times crystals of black color are apparent in the dark ground mass. A feature of these rocks and of the andesites as well, is the weathering or splitting into so-called “basaltic columns.” The rock mass parts or cleaves into long prisms, roughly hexagonal in cross section, forming a cluster of natural columns.

5. *Limburgite.* This rare and unimportant family of volcanic and intermediate rocks is mentioned merely to complete the account of the massive igneous rocks. This family is composed entirely of dark minerals set in a paste of the same or of glass with identical chemical composition. The color therefore is black or greenish black when fresh, weathering to a dark red.

THE TUFFS AND AGGLOMERATES.

Thus far have been listed only the massive igneous rocks; there is a minor group of rocks formed by fire agencies, of much less geological importance, but of considerable value as building material. This group is constituted by the fragmental igneous rocks, or tuffs and agglomerates.

1. *Tuffs.* These rocks are volcanic ashes and cinders more or less consolidated into firm stone. They are composed of finely divided glassy substances, rock fragments of the various igneous rocks, and often with mineral grains and large pieces of stone. They are named in accordance with the chemical family to which they belong. Thus, there are (1) rhyolite tuffs; (2) trachyte tuffs; (3) andesite tuffs, and (4) basalt tuffs. The rhyolite tuffs are most common.

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2. *Breccia*. This variety of fragmental rock is composed of pieces angular in shape and varied in size, usually of only one kind of rock. They differ from tuffs in that they are not ashes, but made up of rock fragments of some size, and have originated either by the explosive action of a volcano or the crushing effect of pressure exerted in the earth's crust. The fragments are usually cemented by a paste of the same material, finer in grain.

3. *Agglomerate*. This rock is most simply described as a mixture of various kinds of volcanic rocks in the form of semi-angular or rounded boulders, small pieces and even ashes. Many agglomerates are hardened volcanic mud containing stones like plums in a pudding. The term is *agglomerate*, to distinguish it from *conglomerate*, which latter term is applied to consolidated gravels deposited by water. Both names mean, however, a mixture of materials.

THE ATMOSPHERIC ROCKS.

This grand division of the rocks embraces those which owe their formation, directly or indirectly, to the decomposing action of atmospheric forces on previously existing rocks. Their structure is that called stratified, meaning in beds or layers. The whole division is often called the stratified rocks. But as all the varieties are not truly stratified, the term is not all embracing. In general there are two primary divisions of these rocks, of very unequal importance. They are as follows:

- I. *Eolian or wind formed rocks.*
- II. *Aqueous or water formed rocks.*

1. *Eolian rocks*. These rocks are of no importance in the present connection, and will be dismissed with a few words. They consist mainly of those materials piled up by the wind, such as the sand dunes of our coasts. Their recent deposition and geological youth prevent any great amount of consolidation, hence the group needs no further mention.

2. *Aqueous rocks*. This group is often called the sedimentary, because they are largely composed of sediments deposited by water action. The name is misleading, for they are not all sedimentary in origin. It can be stated, however, that they have been deposited in or by water. The materials composing them are (1) the residue from the waste of other rocks and derived directly from them; and (2) that material derived

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from other rocks by their decomposition, held in solution in water; and deposited either by the action of living organisms or by chemical precipitation. Therefore under this head come two divisions:

- a. *Sedimentary Rocks.*
- b. *Organic and Chemical Rocks.*

Under the action of the atmosphere a rock breaks down into soft incoherent material by the leaching out and removal of its soluble parts, leaving an insoluble residue. Thus a granite disintegrates into a sandy soil, mostly quartz and feldspar, moistened with alkaline water. Ultimately nothing is left but quartz and clay, stained with iron oxide and containing water alkaline with potash, soda and lime. In general it may be stated that quartz and clay are the two least soluble minerals commonly encountered, and hence, singly or together, mark the end of the decomposition of any rock. It is to be noted that from all rocks except the most acid lime is washed out as well as potash and soda, and the more basic the rock usually the more lime. The alkalies play no particular part in rock building but the lime does. Hence in this brief and popular exposition it may be considered that a decomposed rock will yield quartz sand, clay and a solution of lime. The metallic oxides, such as iron and manganese, remain as coloring materials merely, and are of no essential importance. However, as few rocks break down into their ultimate products before being consolidated into new rocks, we may expect to find, and do find, nearly all aqueous rocks to be neither pure quartz, pure clay, nor pure lime. Keeping these few facts and causes in mind, the principle varieties will illustrate their results.

SEDIMENTARY ROCKS.

1. *Conglomerates.* These rocks are consolidated gravels, resulting from the wear and tear of waves and currents upon preexisting rocks. The material composing them consists of rounded fragments of various sizes, often cemented by finer material of like nature. These pebbles or boulders, as the case may be, are often of various kinds of rocks, while again they may be all of one sort.

2. *Sandstones.* The name of these rocks explains their nature; a stone built up of grains of sand. The ideal sandstone is composed of grains of pure quartz, representing the last stage

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of decay of preexisting rocks. But as most sand is not pure quartz, neither is most sandstone of pure quartz grains. As a result, these rocks have a variety of colors, depending upon the materials present. The most common minerals are quartz, feldspar, mica flakes, garnet and many other dark kinds. There is also another important quality of sandstones. Such rocks are composed of a mass of grains of sand, set in and cemented by some other substance. The three important cementing materials are (1) silica or quartz; (2) lime, and (3) iron oxide. Combinations of these may occur. The first will give a more glassy appearance to the rock and the color will be nearest to that of the original sand grains. The second will give the rock a white color as a rule; the third will give the stone that red color so desired for architectural purposes.

3. *Clay Rocks.* The one rock name necessary to name under this head is *shale*. A clay or mud, when hardened by natural processes, becomes a shale. A pure clay makes a pure shale; a sandy clay a sandy shale, and so on, with all gradations into the sandstone. These rocks are of no value whatever for the purposes of this report, but the clay rocks mentioned under the last grand division of the metamorphic rocks, the well known slates, are very important.

ORGANIC AND CHEMICAL ROCKS.

There are only two varieties of these rocks of any particular value in this discussion. They are these:

- I. *Siliceous Rocks.*
- II. *Lime Rocks.*

Both owe their origin to the fact that certain minute animals secrete either lime or silica from the water, and on dying their remains accumulate in certain places to form rocks. Also chemical reactions play a part in accumulating both kinds of substances. The first, or siliceous rocks, are formed largely by the growth and death of certain low forms of life, as sponges; the second are due in large part to the well known coral polyp.

1. *Siliceous rocks or cherts.* These rocks are very fine grained, sometimes almost glassy in appearance, and of various colors from white to red, green and black. They are well known under the name flint or chert. The fact that they are seldom pure silica results in their various shades of color. They are of



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no use as building stones, but some have achieved success as road metal.

2. *Lime rocks or limestones.* Under this head come the limestones, so well known to everyone. In color they vary from a pure white through the grays to a dead black, the black being due to carbonaceous material. The texture varies from a medium coarse grain to very fine or compact, that is, showing no crystal forms to the naked eye. The crystalline varieties are least common, and are not marbles, which are metamorphic rocks. The crystals of the limestone are due to simple solution and redeposition, while the marbles owe their crystalline texture to other causes. A drop of a weak acid will always serve to identify the lime rock, as a bubbling of gas is caused.

METAMORPHIC ROCKS.

In this division is treated those rocks which have been changed from their original condition by heat and pressure into new forms. They are derived from both the igneous and atmospheric rocks. Geologically they constitute an extremely important and interesting class; economically they are of little value. A few statements will serve to distinguish the main types. They will be taken up in the following order:

I. Gneisses and Schists.

II. Slates and Quartzites.

III. Marbles and rocks altered chemically.

GNEISSES AND SCHISTS.

The gneisses are usually rather coarsely crystalline rocks which show a laminated or banded structure due to a flowage under pressure. In mineral content they correspond in most cases with the plutonic rocks, differing from them in the evident structure. A few varieties are derived from the atmospheric rocks, as conglomerates and sandstones. The banded structure is made evident by the arrangement of minerals in more or less parallel planes. The colors vary precisely as do the colors in the rocks from which the gneisses have been derived. The different varieties are named in a general way from the rock from which the gneiss has originated or resembles most closely. For instance, there are granitic gneisses, syenitic gneisses, conglomerate gneisses and so on.

The schists are similar to the gneisses in that they are banded

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or laminated, but differ in that these laminations are much finer, giving the rocks the power of splitting along fairly parallel planes. With an elimination of fine distinctions, then the schists are finely laminated or foliated rocks rather fine in grain, with mineral content roughly parallel to that of the gneisses and hence to the plutonic rocks. Their most obvious difference from the gneisses, into which they grade, is in their finer banding. In color they range from white, in the quartz schists to black in the basic varieties. They are named from the dominant mineral showing, which mineral is usually arranged in more or less parallel layers, and causing the rock to split readily along these planes. The schists are derived both from the igneous and the atmospheric rocks. The two chief varieties are the mica-schists, showing bands of brown, black or white mica, and the hornblende-schists, otherwise called amphibolite-schists or greenstones. None of these are of particular value in this paper.

SLATES AND QUARTZITES.

When an ordinary clay rock, or shale, is squeezed under pressure, as often happens in mountain regions, it is made to flow at right angles to this pressure. Certain molecular changes set up in the mass cause it to assume a structure which results in its splitting easily along parallel planes into thin slabs. This structure is called slaty structure, the cleavage is slaty cleavage, and the rocks themselves are slates. They are formed in similar manner from igneous rocks also. The typical slate is not crystalline; some varieties show incipient crystallization and shade by insensible gradations into the schists. Their economic importance is too well known to need discussion.

The quartzites are rocks composed chiefly of silica, or quartz. They have usually been derived from siliceous rocks, as quartzose sandstones, by the addition of more silica, binding the whole into a hard, compact mass. Geologically no, old sandstones frequently are converted into quartzites by long continued action of heat and moisture. Quartz schists and quartzite gneisses, and, in fact, all metamorphic rocks mainly silica, come under this head.

MARBLES AND CHEMICALLY ALTERED ROCKS.

The marbles, properly speaking, are those rocks which have been derived by the crystallization of the limestone by the action of heat and moisture with perhaps pressure. They are often of coarser grain than the crystalline limestones. The pure

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varieties are white in color, composed entirely of lime, or lime and magnesia. When made from impure limestones the impurities crystallize out as other minerals, of varying shades from white through reds and greens to black. The purer varieties of marble, which are of value for ornamental stones, are of even grain, the crystals showing shining faces. The test with acid always serves to identify these rocks. It is to be noted that there are two kinds of limestones; (1) those composed entirely of lime, and (2) those composed of lime and magnesia. The second, or lime-magnesia rocks, are called dolomites, or dolomitic limestones, when only a small percentage of magnesia is present. In appearance there is usually no difference; the dolomites are less acted upon by a cold dilute acid.

The *serpentines* are a group of chemically altered rocks of light or dark green to greenish black color, and usually of very fine grain. Sometimes well formed crystals with shiny surfaces are seen set in the finer material. These rocks have resulted from the chemical addition of water to the peridotites, or ultrabasic plutonic rocks. They are of some value as ornamental stones.

Steatite, better known as talc and soapstone, is also a chemically altered rock, similar to serpentine. In color the pure varieties are greasy white, often with a light greenish tinge. They are best known by their greasy feel. Other types of these altered rocks exist, but none of importance in this place. Steatite is often used for furnace foundations and other places where a fire proof material is needed.

This subject of rock classification is one of great complexity and difficulty, particularly in regard to the grand division of the igneous. Necessarily the matter has been presented as one concerned with hard and fast rock varieties, with more or less fixed differences. This is not so, for there are no well defined lines separating any of the various rock types, yet after all, it is the types which are of particular value here, and not the finely drawn conditions and conclusions of petrography.

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CHAPTER III.

QUALITIES OF BUILDING STONES.

This chapter is divisible, by reason of its nature, into three parts. One speaks of the qualities of a certain stone, with its consequent value for architectural purposes. These qualities are of value, first, because of the inherent power of the stone to resist those changes which tend to impair its usefulness, and second, because of the resultant appearance of the rock. These characteristics are estimated in a number of ways. Hence, the divisions of this chapter are as follows: First, an account of the many possible changes to which a building stone may be subjected; second, a description of the features which govern these changes; and third, a brief notice of the ways in which these these qualities are estimated. The treatment of all this will be brief, a full discussion being reserved for a detailed report to be issued at a later date.

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CHANGES IN ROCKS.

These will be discussed under the following outline:

A—*Physical Changes*, due to

- I. Temperature changes.
- II. Mechanical wear and tear.
- III. Effect of pressure.

B—*Chemical Changes*, due to

- I. Atmospheric solution.
- II. Decomposition of certain minerals.

PHYSICAL CHANGES.

I. *Temperature*. The results under this division are of two sorts, and due to different qualities in any particular stone. The first are those results produced by the alternate expansion and contraction of a rock, and, of course, of its component minerals, due to heat and cold. This process is the most important method of rock disintegration in regions of little moisture, as in our typical deserts of the west. During the day the stone becomes warm, or even hot, and expands. At night the temperature lowers, the stone contracts, and the changes being usually rather sudden and of unequal amounts in all directions, chips of rock fly off. The Indians use this principle in manufacturing arrowheads. After heating a suitable fragment in a fire, by

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touching any desired portion with a drop of cold water, unequal contraction is produced and a small piece chips off. In regions of equable temperature, as along the western coasts, little is to be feared from such action; in Nevada, where the daily changes are often pronounced, some importance is to be attached. The mineral composition and texture of a building stone largely determine how greatly it shall be so acted upon. The loose textured fragmental rocks suffer least, because of their ability to take up without rupture small inequalities of motion in their mass. The massive igneous rocks suffer most because of their internal rigidity and the fact that each one of the constituent minerals expands and contracts differently from the others. The volcanic or partly glassy igneous rocks are probably most liable to such disintegration, the plutonic, because of their interlocking grains, are less so.

The second result from temperature changes is due to the freezing of included water. All rocks are porous to a greater or less extent, the crystalline least of all and the fragmental most so. Also the tendency of all rocks to break into large fragments or masses, often rudely regular in shape, by means of parallel cracks, or joint planes, as they are called, allows water to act in this way. The massive rocks especially are subject to jointing action, which may be either on a large scale or a very minute one. In some instances these joints become apparent only on the weathering of the stone. Water, penetrating the free spaces and cracks in rocks on freezing expands, and exerts a tremendous force acting to disrupt the material.

2. *Mechanical wear and tear.* The conditions under which a stone is to be used determines very largely the changes coming under this head. Stones for paving, for tiling, for floors, and for walks, all must be chosen to resist the constant wear of pressing feet and vehicles. Rocks for curbing, subject to hard knocks and the rubbing of wagon tires, must be had resistant to such abrasion. Such stones should be homogeneous and without flaws, otherwise disastrous breakage may occur. Two less important considerations in this connection yet of too great value to omit, are (1) the action of wind, bearing sand and other particles, on the rock of a building; and (2) the erosive and wearing effects of water, particularly in a country of considerable rainfall. The hardness, toughness and texture of a building material govern its strength or weakness, of which more will be stated further on.

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3. *Effects of pressure.* The most important consideration here is, obviously, the fact that a stone selected for purposes of construction must be sufficiently strong to withstand all the force applied to it. For buildings not of large size the average stone has strength far above that required; in large structures some attention must be paid this factor of utility. The effect of pressure or strain on a rock is that of crushing, each variety of building material having its own crushing strength, as it is called. These figures, expressed in pounds per square inch mean the force necessary to crush a cube one inch on an edge. Some average figures are as follows:

Granite—15,000 to 40,000 pounds per square inch.

Volcanics—10,000 to 30,000 pounds per square inch.

Marble—15,000 to 25,000 pounds per square inch.

Sandstone—4,000 to 8,000 pounds per square inch.

Tuffs—2,000 to 6,000 pounds per square inch.

Results both above and below these are often obtained, the hardest granite and rhyolite showing a strength of about 50,000 pounds per square inch of surface, while other varieties will crush at a pressure of 10,000 or 12,000 pounds, or even less. In use, a factor of safety, usually of from six to ten, is employed. But there is more to the crushing strength of stone, however. An important relation exists between the strength of a building material and its structure. A limestone or sandstone, for instance, is much more able of sustaining a given load when laid parallel to its bedding plane. It is a well known tenet of the masonry trade that a stone should never be laid on edge, particularly one of the sedimentary or laminated rocks. The same holds good in the other rocks, even seemingly structureless granite, for there is often some one direction in which such a rock will cleave or break most easily. This plane should always be laid at right angles to the direction of pressure. Lastly, there is a further consideration growing out of all these facts. All stones are brittle, hence must be handled carefully to avoid shattering. The most incipient fractures, of microscopic dimensions, will in time ruin even the hardest rock. Quarrying should be done by the most approved methods, so that this danger of ruining future buildings shall be reduced to a minimum.

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CHEMICAL CHANGES

1. *Atmospheric Solution.* Under this head comes the mere dissolving out and carrying away of certain parts, or the whole, of a rock. The chief agent of atmospheric action is carbon dioxide or carbonic acid gas, which in time decomposes nearly every rock forming mineral. Marbles, limestones and such rocks dissolve completely. Other rocks, as granite, have certain elements leached out, causing a crumbling of the remainder. The alkali metals enter into minerals and compounds which are easily extracted by the water. The decomposition of granite into sand composed of quartz, feldspar and other mineral fragments has been mentioned under the atmospheric rocks. The densest and least porous of the rocks are obviously least liable to this action of solution, and a compact marble, if not broken or shattered in any way, resists for a long time the attack of the atmosphere. In the igneous rocks the iron bearing minerals are easily acted upon and partially leached out. Hence the mineralogical composition of a stone has an important bearing upon its commercial value.

2. *Decomposition of certain minerals.* Here will be briefly outlined some noteworthy results produced by the decomposition of certain minerals. The oxygen and water vapor of the air, combining with the sulphide minerals, such as ordinary pyrite, produce sulphuric acid and iron oxide. This strong acid rapidly attacks the minerals with which it comes in contact, while the iron oxide stains the rock a yellowish or reddish. Pyrite is common in all rocks, and lessens their value for structural purposes in proportion to its relative abundance. An abundance of iron in any rock will cause it in time to become stained a disagreeable yellow color. There are many other reactions of a similar nature, but of subordinate importance and do not need mentioning. The ultimate value of a stone is greatly influenced by these considerations.

II. ROCK CHARACTERISTICS

1. *Color.* This feature of a stone is governed by the colors and relative amounts of its component parts and minerals. For instance, a granite is gray because of the blending of the black mica, white feldspar and colorless quartz. The value of a stone is largely governed by its color, irrespective of other characteristics. Other things being equal a red sandstone will be more sought after than a dull gray one; a red granite will often com-

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mand a higher price than one with a somber hue. The variation in tint of any particular rock also changes its commercial value, as uniformity in all things is desired. Many stones, otherwise first class, are denied a place in the market because of such a defect. Besides the variation in color of a stone from one point to another, it is also to be noted that on drying or mere exposure to the air, some change in the tint may occur. This may be a deepening of color due to partial oxidization or surface chemical change; again it may be a bleaching due to drying. Often a rock with an abundance of iron assumes a reddish or dark red hue, due to the deposition of iron oxide throughout. Many of the Nevada andesites now used in construction are thus altered. The color is pleasing to the eye, but the stone is weakened in the process. Sometimes it is less a change of color than a decrease in the luster of a rock surface. This effect is common on granites, whose materials become either slightly altered on their exposed parts, or covered by a film of dust.

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For ornamental work, as in cornices and monuments, the ability of a stone to show a contrast between the appearances of its polished and rough hewed surfaces is of great value. The crystalline rocks possess this power in the highest degree, because of the fine polish possible. When such materials are carved and their exteriors smoothed, the contrast lies in the fact that a broken surface reflects more white light, while the polished surface, which exhibits the colors of the minerals, absorb more of the sun's rays. A certain granite, valuable as a building material and monumental stone, polishes a very dark gray, while roughing to a light or whitish gray tint.

The selection of color is mainly from two standpoints: taste or fashion, and utility. In regard to taste, there is nothing to state from the view point of this paper except that, other things being equal, a warm tint is preferable to a colder one. Concerning utility, it needs to be emphasized that certain colors are more suitable for particular localities, as, for instance, a gray sandstone should be selected for a building in a manufacturing center, where smoke, dust and grime are ever present. And on the other hand, white stones should be used only where least exposed to tarnish.

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2. *Hardness.* The hardness of a stone is its resistance to abrasion, shown usually by resistance to rubbing. Necessarily, the most important characteristic of a rock underlying this is its mineralogical content, a rock containing an abundance of the

harder minerals, as quartz, being the hardest, and, as all minerals vary in hardness, their relative abundance, state of aggregation, and size of crystals, govern the resistance of a stone to abrasion. A sandstone composed of grains of hard quartz may be very soft because of the loose hold they have upon one another. The chief reason for the greater hardness of the plutonic rocks is because their component minerals mutually interlock and bind the whole firmly together. Also in the metamorphic quartzites, the little broken pieces of quartz have grown by the addition of more silica until a similar interlocking texture is produced. A sandstone cemented by lime or iron oxide is softer because the grains do not bind one another together. In all the sedimentary and laminated rocks variations in hardness may occur in the different layers or laminae caused by a change in any or all of the conditions of the minerals mentioned above. As a result, much care must be exercised in their use. In the crystalline and more brittle rocks it must be kept in mind that even the slightest shattering by improper handling lowers the hardness and hence the value.

3. *Strength.* The strength of a stone is its resistance to applied pressure, either compressive force or transverse strain. This quality is very closely allied to hardness and depends in general upon the same internal conditions: mineral content, state of aggregation, and size of grain. As has been pointed out under "effects of pressure," in large structures the power of a stone to sustain a load is of great moment, while in small buildings and other ordinary uses, it matters little. It is not an unusual sight to see in large stone structures that the material near the base shows undoubted signs of crumbling, due to an overload. Every edifice erected is constantly jarred, and this small inappreciable motion has its lasting effect upon a rock already taxed to sustain a weight too near the limit of safety. More facts pertinent to this matter have been mentioned under "effects of pressure."

Another characteristic of certain building stones has a direct bearing on both hardness and strength. It is the power of some rocks to harden, or temper, on exposure to the air. In particular, some of the tuffs show an ability to temper to considerable hardness, at times sufficient to turn the edge of an ordinary hammer. The last bit of interstitial water of the rock, on working its way out to the surface, deposits whatever it holds in solution in the outer parts of the mass, and at times a perceptible crust is formed,

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qualities of a building material, and such a search is incomplete without this investigation.



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CHAPTER IV

BUILDING STONES OF NEVADA

In actual amount, Nevada is well supplied with rocks which can be used as building material. At present, with a territory only beginning its true development, comparatively little is used, and few quarries are opened. Were the following list taken only from those actually quarried, a poor showing would be made. It has been the aim to include also those rocks which can easily be made use of at a profit, in order that both capital and attention may be attracted. All throughout the west, a region of first class building stones, the fact remains that the value of imported stone runs annually into the hundreds of thousands of dollars. The reason seems to be that people refuse to take advantage of natural opportunities and to develop their own resources, largely because imported material is easy to obtain and is less common than home products. It is true that the commoner uses of stone, as curbing, abutments and some buildings, are supplied by materials produced here, but for the finer uses a very large percentage of imported stone is placed. The west suffers from a lack of red granite for ornamental work, as in monuments, yet there is some first class rock of this color both in Nevada and California which should be developed. At the present writing, nothing can be given in the way of figures of invested capital, costs of handling stone, wages, et cetera, for the simple reason that they are not obtainable. Not one quarry in the state is working, and except when a lot of stone is needed for some sudden purpose, no work is ever done. Needless to say, the capital invested is at the most but a few hundred dollars, outside the value of the land, hence is not important. The location and the possibilities of building stones are the most valuable part of what follows. Much in this chapter will be of no immediate value; much will be fragmentary, for it is difficult to obtain accurate data throughout. Many of the important qualities of a stone can be determined only after a quarry face has been opened, and as yet the University is not equipped with a testing machine, hence it will be some years before a detailed report can be published.

The rocks will be mentioned in the order given in the classification in chapter II, beginning with the plutonic igneous, or, as they are sometimes called, the "granitic rocks."

PLUTONIC OR GRANITIC ROCKS

Under this division there are several important stones actu-

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ally in use, and others with first class possibilities. And in classifying these rocks a slight difficulty is presented. Such rocks are called popularly granites. Some of them are granites; others are not, but all are related. The geographical belt lying on the east flank of the Sierra Nevada and along the foothills is characterized by an abundant development of these, all more or less connected in origin, yet varying from those properly termed granites to those of dioritic nature. As a group, chemically they stand between these two types of plutonics, containing an excess of soda over potash, and often considerable lime. Some contain an abundance of free quartz, others show little to none. As any petrographical discussion is here out of place, only a few remarks of this nature will be presented under each rock. The writer hopes to show later, in a petrographical paper, the true relationships of the granitic rocks of this western portion of Nevada. For the present, the term granite will be used exclusively for those rocks showing free quartz.

GRANITES.

Laughton's Station: This stone occurs in the immediate vicinity of Laughton's Station, to the north of the Southern Pacific Railroad track, about five miles west of Reno. Considerable amounts of rough stone have been taken out at the outcrop directly on the railroad, but no real quarry face has been opened. In color this granite is a medium to light gray, with occasional splotches of a darker shade. The rock is able to take a good polish, quite in contrast to the rough finish. Considerable joint structure is developed on a large scale, sufficient to make quarrying easy, and yet not enough to preclude the possibility of extracting large blocks. The texture is of medium fineness, or grain, in the main phase of the stone, but varies considerably. The normal rock has much more white mineral than dark, but often rounded spots occur which contain a much larger percentage of black constituents. These spots are at times thickly interspersed throughout the main mass; often they are seen as isolated dark centers surrounded by many feet of surface of the normal variety. The minerals to be seen by the naked eye are quartz, feldspar both orthoclase, the potash variety, and plagioclase, the soda-lime variety, brown mica, and black hornblende. The mica is the chief dark mineral in the normal rock, but hornblende preponderates in the dark spots. Under the microscope the orthoclase feldspar is seen to be in crystals much larger than those of the other minerals, and is also greater in amount than the plagioclase.

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The quartz is not in great percentage. Little or no pyrite is present. As in all granite, the hardness is considerable. The rock is rather brittle, and the crushing strength is medium for a granite, the variation in grain lowering this value. The stone, because of its location on the railroad, is available at once and in large amount. The railroad owns that part of the mass now quarried at all, and can furnish vast quantities when required. Unless a well opened quarry should show a more uniform grade of material, the uses of the stone will be limited. It can be used for ornamental work if no variations in texture are present, and for all the more common demands, such as foundations, curbing, walks and the like it will give satisfaction.

Verdi: In the vicinity of the town of Verdi, which is about ten miles west of Reno on the Southern Pacific railroad, considerable areas of granite exist. Much of it is directly on the railroad, south of the town, along the Truckee river. From Verdi to the south the surface rises steeply for about two hundred feet to a level terrace of granite, with boulders of andesite dispersed over it, the last remains of an extensive flow. Several faults occur on this terrace, with resultant rise of the plutonic rock and increased opportunity for quarrying. No quarrying has yet been done, but the possibilities are surely worth serious consideration. There are two types of granite which will be described.

1. This first type of rock is that which makes up most of the mass. The color is a rich dark gray, with a faint trace of pink, giving as a result a very handsome stone. It is able to assume a high polish, showing quite dark in comparison with the rough surface. As no quarry face has been opened, nothing can be stated about the structure of the rock, except that as some faulting has occurred, joint planes are probably developed. From the outcrops existing, the texture appears fairly constant, there being a slight change in color in widely separate localities. However, the stone seems to be remarkably free from imperfections in this respect. The minerals present are quartz, feldspar, mostly orthoclase, hornblende, and mica. The hornblende is the more plentiful of the dark constituents. The pinkish tint is due to the color of the orthoclase, which is a pleasing flesh color. Quartz is not very plentiful, whereas the black minerals are, hence the dark color of the whole. The sulphides are very small in amount. The hardness and toughness are perhaps a little higher than in the Laughton stone, and sufficient for all purposes. But like the Laughton stone, it is so situated that it is available at any time with lowest

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possible cost of handling. An opening to exhibit the character of the mass is all that is needed to show it up properly. For monumental work as well as for all the best uses, this granite should find a ready market, if present indications have much weight.

2. The second variety of granite from Verdi is found at present only in boulders lying on the worn surface of the other. It undoubtedly occurs as veins in the main mass, and should properly be called a pegmatite. These dykes must be of large size, because of the dimensions of the largest fragments derived from them. A quarry is necessary to outline any facts about the matter. The color is either a light red ground through which are irregularly dispersed black shining crystals of tourmaline, or more rarely, a white ground with the dark mineral. The general effect is very pleasing to the eye, presenting a sharp contrast to the other variety of granite. The texture is peculiar, for the minerals are not at all regularly distributed. The mass of the rock is made up of quartz and feldspar, usually redish orthoclase, through which occur bunches of black tourmaline crystals. The quartz and feldspar are of fine grain, while the black mineral, in coarser crystals, is in spots in size from a quarter of an inch up to a foot or more. The stone will take a high polish, differing little from the unfinished surface in shade. It should meet with favor for some kinds of ornamental work, as well as for building material, if it can be obtained in large enough amount.

Washoe: This granite outcrops west of the old town of Washoe, on the Virginia and Truckee railroad, and is a part of the great granite mass occurring at the east base of the Sierra. A quarry is opened about a mile west of the town, on land owned by Mr. John Barrett, the stone cutter of Reno. Not a great deal of work has been done, yet the stone has been shown to be of fairly uniform color and grain. The color is a medium dark gray, with a very faint pinkish tinge, lighter than the Verdi rock. There appear to be few or no imperfections in structure debarring the extraction of large pieces for use, but, in common with most of these rocks of the region, the texture varies somewhat. At times splotches of dark constituents occur to mar the even aspect of the surface. Careful selection, however, should eliminate this evil. A good polish is taken, quite dark compared with the unfinished stone. The minerals are quartz, both varieties of feldspar, mica and hornblende. The two dark constituents are about equal in amount while the quartz is sparingly distributed. The sulphide minerals are rare, as in all of these rocks. Both hardness and



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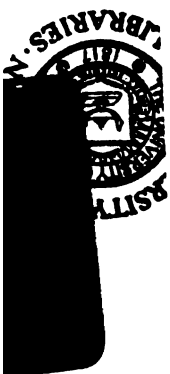


toughness are fairly high, and should improve as deeper cuts are made in the quarry. This stone is not quite so readily available as those already mentioned, as a haul of a mile to the railroad is necessary. At present the granite is used for monuments and ornamental purposes by Mr. Barrett.

Nearer the railroad, and in fact, directly on it, is an occurrence of volcanic and plutonic boulders, in which are some of granite. This stone is the same as the Washoe granite just mentioned, and is quarried by the railroad for use in culverts, abutments, and the like. Such a source is, necessarily, limited in extent, yet it does sufficiently well for immediate needs. And it may be well to note here that most of the granite now used in and about Reno for curbing, mounting blocks, and such commoner demands, is obtained from the vast quantity of boulders existing in the river wash covering much of the adjacent territory. It is needless to remark upon the cheapness of this source, yet the best quality of material cannot be furnished in such a way, so that the ultimate cheapness is lessened. Only a well opened quarry will deliver the best stone, and when substantial, long-lived buildings are to be constructed, field boulders should never be used unless of exceptional size.

Ophir: This rock is well exposed at Ophir, about a mile northwest of Franktown, on the Virginia and Truckee railroad. A little preliminary quarrying has been done at a point just south of the wood flume, on the small creek here draining down from the mountains. The stone rises up about a hundred feet above the creek, giving some opportunity for working. As yet the solid mass of the granite has not been reached, the quarrying has been done in the more or less broken surface material. The color is the lightest of all those described being, in the average, a very light gray. Some varieties, small in amount, are darker in shade. A good polish is possible, which is little darker than the rough surface. Jointing is well developed, insuring ease in quarry work while not preventing the extraction of large blocks. In texture the rock as a whole varies considerably, though the main mass is fairly constant. Normally the crystals of the component minerals are fine in grain, with longer black crystals sparingly distributed throughout. The minerals of fine even grain are quartz, both feldspar and brown-black mica, the larger black crystals are hornblende. The quartz is very plentiful, giving almost a glassy luster to the rock. Also, many small grains of a yellowish mineral are dispersed rather plentifully. The other varieties are due to the

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change in the relative amounts and kinds of the minerals present. Some show an abundance of large shining mica flakes with little or no hornblende; some show much hornblende with no mica; and others show a great amount of clear colorless quartz. These, however, are in small amount. This granite is very hard, but more brittle than the others. Its availability is apparent, being less than a mile from the railroad. Its possible uses are limited by its variation in texture to the commoner ones, such as curbing, mounting blocks, foundations, and pavements, though its light color might find favor for contrast in monumental work.

Lakeview: This stone is well shown in the railroad cuts south of the station of Lakeview, three miles northwest of Carson on the Virginia and Truckee railroad. The railroad grade winds around a hill composed chiefly of this rock, thus making it possible to obtain vast quantities at a minimum cost. No quarrying of any sort has been done, as the stone is not of the best quality for building needs. The color is a light gray, similar to, but darker than the Ophir granite. In the exposed outcrop many little dots of red are to be seen on careful inspection. The mass of the rock is quite faulted and jointed, but blocks of large size can be taken out, judging by the weathered portion. The texture is rather coarse in appearance, because of the large size of the hornblende crystals; the light colored constituents are of finer grain. The minerals are quartz, feldspar, again both kinds, with a slightly larger percentage of orthoclase, hornblende and mica. The hornblende is the chief dark constituent. Quartz in nominal amount. A considerable number of small grains of a yellowish mineral are present, as in the Ophir stone. One other substance is worthy of notice; the mineral magnetite, which shows quite plentiful under the microscope. Such a rock as this is limited in usefulness to the commoner demands, and it is also possible, on account of the mineral content, to use it as a road metal. Its vast amount, easy of access, its small mica percentage and its comparatively large percentage of iron, make it easily possible that it might prove a success as a material for macadamized roads.

Carson Prison: On the Prison Hill as it is called, a granite similar, or the same, outcrops from beneath the andesite flows. This locality is not on the line of the railroad, but is easily approached by teams. If the stone proves a good road metal, this would make a good locality to furnish material for those parts of the region nearby.

Luning: Near the town of Luning, in Esmeralda county

and five miles from the line of the Carson and Colorado railroad, there is an occurrence of a fine grained white granite. No real quarrying has been done, and only a small amount of stone has been extracted. Small pieces show a finer grain than in the other granites described, and exhibit a contrast with them. The land and stone is owned by Mr. Lindsay, of Carson, who has the stone for sale, as well as for his own use in building work.

Mason Valley: This stone occurs near Mason Valley, in Hudson Pass, Lyon county, about eighteen miles from the Carson and Colorado railroad. As with most of the other rocks, no quarrying of any amount has been done, and the stone awaits a market. The color is rather striking, being a light mottled pink-gray. On close inspection three distinct colors present themselves, due to the different minerals; white, pink and dark green. The polished surface brings these out well, and presents a considerable and pleasing contrast with the rough finish. The grain is medium and even, with an occasional large white crystal. The polish brings out clearly most of the component minerals. To the naked eye no quartz is present, and the rock looks like a syenite, or that rare rock standing between a syenite and a diorite—a monzonite. The minerals easily seen are feldspar, including stout pink crystals of orthoclase, and long white crystals of plagioclase. Under the microscope, quartz is apparent, making the rock a granite though a basic one. Both hardness and toughness are high. The stone is not as available as could be desired, yet its color and other qualities are such that its value is high. It can be used for monumental work, and buildings, and should find a ready market. The owner of the present "quarry" is Mr. Lindsay, of Carson.

Winnemucca: Two varieties of granite are used in Winnemucca. The first is quarried twelve miles to the north of the town, and hauled in by teams. It is a medium light gray stone, taking a fine polish, and is sufficiently good for the best class of work. The grain is of medium coarseness, with little variation in color or mineral content. The minerals are the usual ones already mentioned, with not a great deal of quartz. By way of illustrating availability, some figures of cost of hauling for this stone will be given, which are fairly good for others removed from the railroads. A trip from Winnemucca to the quarry and return occupies two days, with a large wagon. Seventy-five cubic feet of stone are hauled at a trip, for which eighteen dollars are charged. This stone has found some favor for monuments in the town, and can

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be used for ornamental and construction work. Mr. Joe Pasquale is owner.

The second granite used in Winnemucca is taken from boulders found on the lower slopes of the mountain bearing the same name as the town. In color and general appearance it is much like the first, but takes a poorer polish. It also has found some demand for monuments and buildings, but is inferior to the first because of longer exposure in fragments. However, it is well adapted to all the commoner uses.

Elko: Much granite exists both to north and south of the town of Elko but at some distance. At present one variety is quarried, and used in the town for nearly all purposes. This rock comes from a spot about thirty miles north, necessitating a long haul. The distance from the railroad limits its use and market, for when a quarry is well opened on the line of the railroad, as can be easily done, at a place like Verdi, such a stone will be driven from use by it's cheaper rivals. It is possible to find some first-class monumental granites in the region about Elko. And there are many other possible stones. Granite is plentiful at Steamboat Springs, and more at Verdi, up Dog Creek Canyon. Likewise in the eastern part of the state there is much similar stone, most of it unknown in value and qualities. But for some years only the most valuable granites existing away from transportational facilities can be available, because of the wealth of easily obtained poorer stone outcropping directly on the railroad lines.

DIORITES

Virginia City: The mass of Mt. Davidson, upon whose eastern flanks Virginia City lies, is chiefly of a dioritic rock. It is not urged that this rock would make a first-class building material, for it's color is a somber gray, it's grain fine, and the whole aspect uninviting. It is mentioned in this place because of its possible use as a road metal. It's constituents are feldspar and hornblende, with usually some iron pyrite. The texture is one of interlocking crystals, causing very great toughness. There are several phases of the stone, each with it's own color and general appearance. The summit outcrop develops a gray granite looking rock; the tunnels and crosscuts in the mines often show a much darker variety. For a road metal, the binding power should be good, while the toughness will be vouched for by every miner who has driven a drill into it. As mentioned in the chapter on road metal, the rock may prove easily a most valuable one for use on roads underlying heavy traffic.

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Beckwith Pass: This rock is found near Beckwith Pass, in California, but as its development must come through Nevada, it is here included. Like all the granite rocks, it exists in practically unlimited quantity. A little quarrying has been done, sufficient to show up the stone fairly well. The color is a very dark gray, darker than the Verdi granite, which it somewhat resembles in appearance. It takes a perfect polish, which does not present a great contrast to the rough surface, as the stone is essentially so dark. The grain is of medium coarseness, and very constant; the stone is quite free from irregularities of all sorts. The minerals present are plagioclase feldspar, with mica and hornblende in nearly equal amount. Black magnetite also occurs. The hardness and toughness are fairly high. It is yet necessary to haul the stone some distance to the railroad, which militates slightly against its use. With the advent of the proposed Western Pacific railroad, this difficulty will be largely eliminated. The quarry now operated is owned by Mr. John Barrett, of Reno, who has been mentioned as owning a Washoe stone. This diorite is now used for monumental work entirely, and is well fitted for all the best class of uses. It also might prove a valuable road material, for which the chippings and waste could find a market.

VOLCANIC ROCKS

RHYOLITES

There are two stones used in Nevada which are classed with this group of rocks. Both are from the region just south of Virginia City, near the American Flat Tunnel on the line of the Virginia and Truckee railroad, in Lyon county. Both are quartz-porphyrates in a general sense, though there are variations from a true quartz-porphry or rhyolite, to a quartz-andesite, or dacite, based on the nature of the included feldspars. In detail these rocks are as follows:

1. The first stone is quarried from the great mass covering many acres, at a point on the railroad one-fourth of a mile west of the American Flat tunnel. The color is a not unpleasant yellowish white, a suitable shade for a dry, dusty climate. The texture is porphyritic, and even throughout large volumes. On close inspection the color is seen to be due to the ground mass; while the crystals showing are chiefly clear quartz, and white feldspar. Some small grains of iron bearing minerals, as mica, are present in small amounts. The general effect is good, a little different from the usual run of stones. The rather large glassy quartz grains, particularly, give the rock a distinct individuality. The

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hardness is high; the toughness a little less, and both rank with the best. Much resistance to atmospheric changes is given, so that long life to a structure of this material is assured. The quarry cut is directly on the railroad, so that any amount needed can be easily obtained, the railroad, of course, owning the land. This stone was much used in the early days on the Comstock, chiefly for foundations. It shows no evidence of change where so used. The railroad now constructs of it abutments, culverts, retaining walls and other similar structures.

2. The second quartz-porphyry is quarried five-eighths of a mile east of the tunnel already mentioned. The color in the mass is a medium dark purplish, which color is a not inconsiderable factor in the worth of the stone. The texture like that of the other, is porphyritic, with well developed crystals of quartz, feldspar, and dark mica. The color is due to the purplish-gray ground mass, in which the other minerals show distinctly. The main difference between these two rocks is in the color, and the increase in the amount of mica in the purplish variety. This latter stone is decidedly pleasing to look upon, and should find favor for buildings. It's hardness, toughness, and other characteristics are identical with those of the first of these rocks, and likewise it is quarried by the railroad and used in some of it's culverts and abutments. It has been used in one of the railroad crossings at Steamboat Springs, and makes a fine appearance.

ANDESITES

There are several quite prominent building stones under this rock group, including some of great promise. As the demand for such materials of construction increases, they should all find ready markets, particularly as they are easy of access and near the centers of population.

Southwest of Reno: This stone is the one used largely in the erection of the new Carnegie Library Building in Reno. It is locally called a sandstone. It comes from one of the large andesite flows which bathed the lower eastern flanks of the Sierra in recent geological time. The quarry is situated at a point about four miles southwest of Reno in an air line, though nearly two miles further by road. The work here has just begun, and is due to the construction of the building just mentioned. Enough has been accomplished, however, to show some of the larger characteristics. The quarry shows well the flow structure of the mass; the planes of motion lie nearly horizontal, greatly facilitating the extraction of large blocks. On this account, the cost of quarrying is very

low, aided also by the absence of any overburden, or surface waste material, beside a few feet of rocky soil. The color is a medium light red or red-gray, similar to but redder than the tint of the quartz-porphry from Virginia City. The texture is porphyritic, showing white feldspar crystals with smaller ones of mica and hornblende, in the red-gray ground mass. The white feldspar is all that shows on a cursory examination, and as much of this mineral is present, the popular term sandstone has been employed. These more or less lath shaped crystals of feldspar are arranged roughly parallel along the flow planes. The red color of the ground mass owes its nature to the decomposition of the iron-bearing ground mass, with the resultant deposition of iron oxide throughout. The effect produced is fair to look upon, but the stone is weakened thereby. The hardness and toughness are low for a rock of this type, and are little better than in an average sandstone. It would crush, probably, at a pressure of about six thousand pounds per square inch. This is sufficient for all ordinary demands, but not enough for the very largest buildings now erected. It will withstand much in the nature of temperature changes, as will all the rocks of this group.

Being situated near Reno, it should be used in many more buildings to be erected in the near future. Its general appearance counts strongly in its favor.

On the western side of the ridge on which the above quarry is situated, is a second outcrop of the same rock. There is a difference, however, for here the red color is replaced by a gray, due to the non-oxidation of the mass. The other features are the same, except that the lasting qualities are much better. The two stones are in pleasing contrast, and will undoubtedly find favor in a short time.

Huffaker: There are two varieties of andesite at this point, five miles south of Reno on the Virginia and Truckee railroad. The railroad here skirts the foot of a rather low hill, on which outcrop the rocks in question. They are both part of the same mass.

The first is a red stone, a shade darker than the library andesite. It forms most of the surface material and can be obtained in quite large amount. No quarry face has been opened, so that nothing can be told about its structure. It has no flow planes like the first mentioned andesite. It is porphyritic in texture, showing well formed crystals of black hornblende, red discolored lath shaped crystals of feldspar, and all in the red ground mass. The hornblende is quite plentiful, the feldspar is about equal in amount, but decomposed and reddened as is the ground mass. The hard-

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ness is medium, the toughness somewhat less. The availability of the material is a strong point in its favor, as it outcrops less than a hundred feet from the railroad track. It is on the Huffaker ranch, and has been used locally to some extent.

The second variety is a granitic looking rock, and by the average individual would possibly be called a granite. It outcrops on the same hill as the other, and, due to the fact that less decomposition has taken place, lacks a red color. It is a medium light gray stone, apparently showing quartz, feldspar, and hornblende. Careful study, with and without the microscope, show it to be a truly porphyritic rock, of medium grain and even texture. The minerals in well formed crystals are white feldspar, black hornblende, and a few flakes of mica, set in a glassy, colorless, ground mass. It is this glass which has the appearance of quartz. The general aspect of the rock is decidedly in its favor. As no real quarrying has been done, and no thoroughly unaltered rock exposed, its other qualities are not known. From its construction it must be a very hard though perhaps brittle, stone. The Huffaker residence, a large two story structure, is made of this material, which shows no change in its thirty years of service. These two andesites are worthy of careful investigation and some work done to exploit them.

Fulton's Quarry: The rock exposed in this place exists to the north of Reno, over considerable territory. The quarry itself, in the best material, is about two miles north of the University campus, just above the line of the Nevada, California and Oregon railroad. What work has been done is all on the surface; no quarry face has been well opened. The color is a light greenish gray in the mass, and a restful one to the eyes, especially in the glare of the sunlight in a hot, dry climate. The rock is rather strikingly porphyritic on close inspection, though of even appearance at a little distance. Large glassy feldspar crystals half an inch in length are frequent. Also, many flakes of dark mica are present, with a little hornblende, and all set in the compact, greenish-gray ground mass. In selected pieces the texture is fairly constant, but as a mass much variation occurs. Inclusions of other materials are found, and small cavities lined with materials are at times plentiful, so that careless work may result in unsightly spots in buildings. The hardness and toughness are fair, and the resistance to weather changes is good. As it is on the railroad, its availability is excellent, and there is a vast quantity in sight. The stone has been used considerably in Reno. Several of the newer University buildings contain it, as the gymnasium and

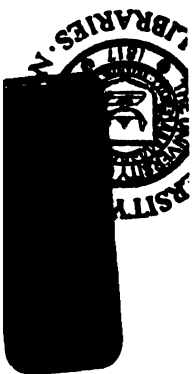
Lincoln Hall, and a few structures in the business part of town are made wholly, or nearly so, of the material. Its greenish tinge gives a pleasing aspect to the buildings containing it. Another possible use is that of road metal. In the search for such material soon to come, a test upon the rock would not be ill advised.

Virginia City: About two miles to the east of the old town of Virginia City runs a ridge approximately north and south. Sugar Loaf peak is part of this ridge, which is cut in two by Six Mile Canyon and Creek. An andesitic rock forms this feature of the topography, furnishing one, and able to furnish two, stones for building purposes.

The first of these is quarried at a point just east of the Brunswick Lode, on the east side of a small hill rising from the ridge. Considerable rock has been taken out here, yet in a more or less careless manner, and no well cut face is shown. The structure of the mass is quite remarkable. Rock columns averaging two feet or more in diameter compose the whole, like a bundle of sticks laid carefully parallel to one another. These columns pitch to the northwest at a low angle, aiding very materially the quarrying. This stone is the most striking in appearance of all those described in these notes, and is almost beautiful. Any one word will fail properly to give the color, for the texture has given the rock a mottled aspect. This texture is porphyritic, and large roughly rounded feldspar crystals often half an inch across, with smaller prisms of hornblende and flakes of dark mica appear in a blue-gray, or steel blue ground mass. The feldspar is quite glassy, much in contrast to the lusterless colored ground. There is some variation in texture, which must be guarded against by selecting only the best. Frequently small inclusions with slightly different color and grain occur, which spoil the even effect of the whole. The hardness, toughness, and other characteristics are good, and need little consideration under ordinary circumstances. The stone is easily obtained, the quarry being less than two miles from the railroad, and an easy haul will deliver it at the station. It was used extensively in the early days of the town for foundations for large machinery. As it yet remains in place, one can see how well it stands. To state that it makes a beautiful appearance does not seem like exaggeration.

The second variety of these andesites occurs in Sugar Loaf, and in the exposed places in the immediate vicinity. It has not yet been quarried nor used. A fine exposure is present to the southwest of the road in Six Mile Canyon just where the bridge spans the creek at the base of Sugar Loaf. This rock is very

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similar to the first, yet distinct in its general appearance. The ground mass is a very light gray, with a faint tinge of blue, and the well formed minerals are white feldspar, in smaller crystals than in the first phase, with black hornblende more plentiful than before, and a little dark mica. The other qualities are about the same as those of the first variety, and are good. A little harder pull by team is required to land it at the railroad yards, yet this will not count much against it. As far as known, this stone has never been worked, but it would make a very good building material.

TUFFS

There are three of these valuable building stones now in use in the state. They are softer than the average consolidated tuff, yet this lack does not prevent their being used in many important ways. They fill a want for certain kinds of materials better than any other stone, and at times rank with the best sandstones.

Merrimac Station: This tuff outcrops in the Virginia Range in the canyon of the Carson river, at Merrimac Station, on the line of the Virginia and Truckee railroad. This point is a few miles east of Empire, and within easy reach of all important points. The quarry, owned by Mr. J. W. Adams, of Carson, is on the south bank of the river, and is one of the very few well opened ones in Nevada. The color of the stone is a light pink, almost a flesh color, and does not vary throughout the mass. As it is composed of volcanic ashes, with some mineral fragments, its texture might be taken to indicate a very fine grained sandstone. The fragmental character is clearly shown, and the absence of stratification planes or layers indicates to the unaided eye the nature of the material. The ash is largely glass, in minute fragments, in which are imbedded angular pieces of mica, quartz, and feldspar in small amount. The grain is very even for such a stone, and its general effect is very good. In hardness and toughness it stands low, about equal to a soft sandstone, too low to warrant its use under much stress. It tempers a little on standing, but not sufficient to raise much its strength. It is rather porous, as are all the tuffs, yet withstanding temperature changes well, because of its internal structure. It has been used very largely in and about Carson and Reno, chiefly for copings, cornices, lintels, arches, and such others requiring little strength. When used with brick, a very pleasing contrast is presented, as is done with any other material harmonizing with it in color. The Gymnasium and Lincoln Hall of the University Buildings both contain it, some brick residences in Reno are much improved by its use;

and the new Elk's Hall shows it to advantage. This tuff should be much used for the demands befitting it.

North of Reno: This tuff comes from a mass of consolidated ash almost twenty miles northeast of Reno, on the Spanish Springs Valley road. A little stone has been quarried and used in Reno in ways similar to the Merrimac rock. Its color is a light pink, a little lighter than the first material. These two stones are very similar in their features and can be used in precisely the same ways and for the same demands. This second tuff, however, is more irregular in texture, containing angular fragments of other rocks, largely andesite and granite, thereby appearing somewhat mottled when closely inspected. It tempers slightly better than the other. Careful selection should eliminate the unsightly stone from that quarried. The owner is Mr. Wm. Schrader, of Reno.

Lovelock: This rock is located in the hills to the northeast of the town of Lovelock, on the line of the Southern Pacific railroad. The point from which it has been obtained is about four miles from the station with not a hard haul over the distance. The color is a purplish-gray, of a medium depth of tint. The structure and texture are in general the same as in the other tuffs. Many small fragments of volcanic rocks are interspersed throughout the mass, and small glassy crystals of feldspar are quite noticeable on careful inspection. The rock inclusions are dark gray, so that a close view exhibits many seeming imperfections in grain. Used in a building these are not apparent, and the whole aspect is a very pleasing one. The usual shade of purple will give a pretty contrast with other stones whose color blend with its own. The hardness and strength are good, ranking well up with that of the best sandstone, while at the same time it is resistant to atmospheric changes. A vast amount is in sight, and when once introduced, a ready market should follow.

Washoe: A rock similar, yet different, from the three tuffs mentioned, is found at Washoe, on the Virginia and Truckee railroad. This notice is of value chiefly from a historical standpoint, as several of the old abandoned buildings of the once thriving town are made wholly of this stone. In its nature it is a volcanic agglomerate, or a consolidated volcanic mud, and an unusual material for purposes of construction. The old quarry is on the hillsides above the railroad track just north of Washoe station, in a surface cut only a few feet in the mass. One is tempted to describe it as having a mud color, this feature is so

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very inconspicuous. More specifically the color is mottled light and medium dark gray, and the surface usually appears dusty. The texture is quite porous. Nothing in the way of definite substances or minerals can be easily determined or distinguished. Its lasting qualities rank with an average sandstone, but its strength is less. It is easily available, but its use cannot be urged in the face of much more and better stone.

ATMOSPHERIC ROCKS

SANDSTONES

Nevada has had developed up to the present time only a few rocks of this family, and none of them can be called first-class. They are all of recent geological age, and owe their qualities to their youth. As the development of the state goes on, more such will surely be found, perhaps some of the very best. These stones will be needed as the cities and towns grow, and the best will command a good price.

Carson: The first and most important sandstone is the well known one at the State Prison, near Carson. The quarry constitutes the prison yard, and has had the most work done of any in the state. The sandstone beds or strata occupy the site of an extinct lake, and exhibit the quite famous animal tracks on the present floor. The color is a yellowish-gray, a gray unfortunately, streaked with a light yellow, and not uniform. The rock is rather heavily bedded, with the bedding planes nearly horizontal. This position is probably the same one the stone has always occupied, although slight tilting may have occurred. On this account, of horizontality, quarrying is easily done. That mineral content shows the stone to be derived from the weathering and decomposition of a granite, the yellowish tinge being due to the oxidation of the iron bearing substances. The constituent grains are cemented by secondary silica. The grain of the rock is of medium fineness in the average, but at times becomes quite coarse, containing pebbles up to half and inch in size. The hardness and strength are medium, sufficient for all ordinary needs, and the resistance to other forms of change is good. There is much material in sight at the prison yard. The stone has been used largely in Carson and Reno. The new chemistry building at the University is constructed wholly of it, and presents a very satisfactory appearance. A small amount has found a resting place in the stone entrance to the University grounds, as is shown in the front-piece.

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Fallon: This sandstone occurs near the town of Fallon, in Churchill county. Little quarrying has been done, but samples of the rock show its main features. In color it is a cream white very uniform in the small pieces shaped for exhibition. The grain, too, is uniform, and quite fine. Its hardness and strength are about equal to those of the Carson stone, and satisfactory. It should resist the weather well, and appear to be a very fair stone for building purposes. Mr. L. B. Self, of Reno, is the owner.

Winnemucca: There are two varieties of these stones quarried near and used in Winnemucca. Neither are first-class in any respect, though they do well enough for the local uses. They are taken from the old lake beds, to the northeast of the town.

The first stone is quarried nine miles from the railroad station and hauled in by team. The color is a light drab, and quite uniform. The minerals and substances comprising the stone do not show, on account of the fineness of the grain. Some black flakes of mica are noticeable, but nothing else. The hardness and strength are low, too low for anything but the smaller structures and the uses demanding little power to withstand pressure or stress. It stands temperature changes well, and were its strength higher would be an admirable building stone. Some new buildings have recently been erected in Winnemucca composed largely of this stone. Such local uses are well met, but the demand for such a rock will of necessity be limited to the town itself. Mr. Joe Pasquale is owner of the stone.

The second variety of sandstone is quarried from a point four miles from the town, and much more available. However, the quarry has been abandoned, on account of numerous faults and breaks in the material, which render the cost of obtaining stone fit for building almost prohibitive. The color is a light gray; the texture is coarser than in the first variety, and somewhat variable. The hardness and strength are considerably more than in the first, so that were the stone to be easily obtained its use would be wide. New developments later may show different and more favorable conditions. The new fire company house in Winnemucca shows a handsome front of this material. Mr. Pasquale is owner of this stone, as of the first.

Elko: At Elko there is a sandstone much like the first one described from Winnemucca. As with the rest of the soft materials, its use is limited to small buildings, where the strain upon it is light. The local demands are met sufficiently well by it, but it can never have wide use. There is surely much first class build-

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ing material to be developed in this part of the state as the population increases.

MARBLE.

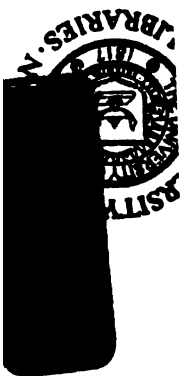
The marbles in Nevada are well represented, although little has been done to develop them. Only a few are quarried, due, of course, to the scattering demand and difficulty of gaining a market against other stone now used. It should not be many years before a steady market is open to them, not only in this state, but in others as well.

La Moille Valley: On the borders of this valley, in Elko county, exists a vast amount of a fairly good variety of marble. No quarrying has been done, but some stone has been taken out to show its character. The color is white in one variety, and a gray, or a laminated gray and white, in another. The white is clear, not marked by yellowish spots or flaws. The stone is rather finely crystalline, and takes a good polish. The marbles are all hard, brittle, and easily, though slowly, soluble in atmospheric waters, as has been discussed in a previous chapter. The rock is not very far from transportation facilities, and should meet with some demand. The uses are mainly interior ones, such as tiling for floors, mantels, mosaic work, and others. Mr. W. T. Crane, of Lee, Elko county, is the owner.

Humboldt Mountains: In these mountains a considerable amount of coarsely crystalline marble exists, which may prove of some value upon more careful investigation. What rock has been seen shows a pure white color with few impurities appearing on weathering. This is not the only place where such rocks are known to exist; it is cited merely as an instance of the little knowledge regarding these things.

Luning: More marble, of gray and white colors, exists in the region in the vicinity of Luning, Esmeralda county. Some of this has been quarried and used by Mr. Lindsay, of Carson, and it ranks with the others mentioned. It outcrops on the line of the Carson and Colorado railroad, hence is easy of access, which is a strong point in its favor. More facts concerning it are needed.

Topaz, California: Considerable marble is found in Antelope Valley, in California, opposite Douglas county, in this State. As its use and development comes naturally through Nevada, it needs a mention here. The stone varies considerably in color, from white to blue, gray, and yellow. As the locality is off the railroad, the development work has lagged, but the rock deserves some atten-



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tion in the near future. The uses are those already mentioned. Mr. Lindsay, of Carson, owns much of the material.

Inyo County, California: Considerable marble has been quarried in Inyo county, California, and used both in Nevada and California for tiling, mantels, mosaic work, and such demands. Some of the rock is laminated; most is not, but cracks and flaws are quite common. There are three distinct colors of the marble, white, yellowish-white, and dark gray. The contrast between these is very pleasing to the eye. The lasting qualities are the same as the other stones of like nature possess. The stone works on the Truckee river above Verdi are handling this rock almost entirely and have some large contracts on hand.

TRAVERTINE.

Bridgeport, California: This variety of stone is related to the limestone, having been deposited by springs. A great deal of these deposits are to be found over southeastern California, Nevada, and Arizona, marking the sites of old springs. The only occurrence yet exploited in or near Nevada to any extent is near Bridgeport, in Mono county, California. The stone is a variegated reddish, and yellowish, very handsome when polished. It was used in the new City Hall in San Francisco. The work of exploitation needs to be carried farther, as it will be when more demand is made for the material. Its uses are purely ornamental.

It is needless to say that very many more stones suitable for purposes of construction exist in the State. Only those actually used, and those about ready to be used, have been listed. There are many more known; there are vast amounts to be discovered.

The frontispiece shows a number of the rocks mentioned actually in use in the "University Gates." The large columns supporting the gates are made from granite taken from boulders near Reno. The smaller pillars just outside are composed of Washoe granite, a shade darker than the first. The stone wall exhibits two more. The first, or ground course of blocks in the wall to the left is made of the andesite from the Fulton quarry, north of Reno. The upper three courses of stone are all the Carson sandstone. The finish throughout is rough, and the appearance very pleasing.

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CHAPTER V.

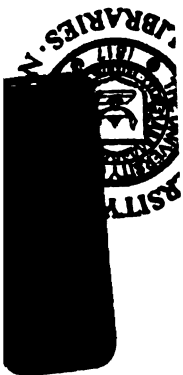
ROAD METAL AND SOME GENERAL PRINCIPLES OF ROAD MAKING.

This subject does not come strictly under the head of building stones, yet its vast importance to the welfare of any community, together with the fact that some knowledge of rocks is essential to a proper understanding of it, more than justifies a short chapter setting forth a few fundamental considerations. The bicycle and other horseless vehicles have done one great work, if nothing else; they have shown conclusively to all people the value and immense importance of good roads.

Time was when the old earth road was held sufficient for all needs, and such roads were not even crowned. We still have many earth roads, which, when properly compacted and graded, do well enough for light traffic in sparsely settled regions. Where travel is at all heavy, however, earth roads become a makeshift, and some material which will not cut to pieces is needed. Very naturally, men have turned to rocks to furnish such material, termed in general, "road metal." The roads made by crushed rock on an earth foundation are called macadam, from the name of the man who introduced them.

For the purposes of road construction we have a vast abundance of rocks of various kinds and character. Bearing in mind the classification of rocks in Chapter II, we realize the range of choice. All of the igneous, atmospheric and metamorphic rocks, of hardness greater than earth, might be used. By class the igneous rocks are hardest, the atmospheric, softest; the igneous are more or less crystalline, the atmospheric largely fragmental. The metamorphic rocks are intermediate in their qualities. In Nevada there is a large development of all these kinds, easy of access. But this wide range of choice not only furnishes abundant possibilities, but also allows the selection of the best. It must be self-evident that all road materials are not of equal, nor anywhere near equal value. There is always a best and a poorest for every case. In order to select the best road metal for a certain street or road, a knowledge of the principles underlying such choice must be had. A brief account of these will be presented.

The fundamental fact on which all road making is done is the simple one that a highway is constructed to withstand constant wear. It must first be known, therefore, of what this wear consists. The wasting of a road is due, first, to chemical agencies; second, to physical agencies; and, third, to mechanical agencies.



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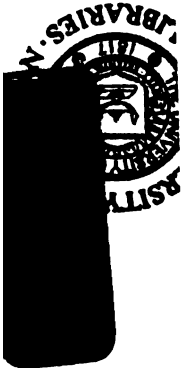
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The chemical agencies are those constantly at work in the atmosphere, and producing (1) solution and (2) decomposition, as pointed out under building stones. The physical agents are likewise atmospheric, and are: (1) frost, producing disruption of the road and of the individual rock fragments; (2) the effects of rain falling on the surface, running off, loosening the road surface and transporting the material away; (3) the wearing effects of the wind in carrying off the fine particles as dust. The mechanical agencies are due to the action of living things; the wearing down and grinding up of the surface; the crushing effect of heavy loads and impact of the feet of animals; and the possible injurious effects of roots. With roads properly constructed, of those forces tending to impair their usefulness the physical and mechanical agents are most important.

Enough has been written of chemical agencies under a previous head, so that a mere mention is all that is here necessary. Such processes in nature are so slow that roads suffer little comparatively from them. However, chemical reactions play an important part in the process of compacting, or binding a road bed and making it durable. This power of binding, or cementing, in a road metal, is an essential quality, and the higher it is the better. All other things being equal, the ideal road material is that one which will furnish a large percentage of mineral, or minerals, that do not alter or which change very slowly, with some other mineral or minerals capable of furnishing, by slight decomposition, sufficient cementing substance to bind the whole together as a solid mass. The particular minerals best fitted to accomplish this end are those containing iron and alumina, with silica. Lime bearing minerals also are valuable. By way of a homely illustration, this process may be likened to a sidewalk made of nails, which, on being allowed to remain for some time, becomes rusted into a solid condition. There are several more important binding materials, as clay, secondary iron minerals, calcite or lime, and sometimes silica. These must form, in order to be of greatest good, in just the right amount to bind the gradually pulverized surface coating, as well as to harden the whole.

Of the physical agencies, in regions of considerable range of temperature, the action of frost may be of some moment. As mentioned under rock weathering, water, entering the pores of a stone and in cracks, on freezing becomes a powerful lever tending to disrupt the material. Also, the mere alternate cooling and warming by daily variation, gradually weakens a rock. In mild climates these things play no part. The effect of rain in loosen-

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ing and wearing away the road surface may become a source of danger in poorly constructed highways. The greater effect of rain is its power of transporting the layer of fine material necessary on every well kept road. This action is measured by the specific gravity of the minerals composing the rock surface, their shape, and their state of compactness. For instance, mica is a poor miner to have in a road metal, because of its flaky nature which allows of its easy transportation by the rain and wind. The selection of a stone must consider all these points. In like manner the winds are constantly picking up and carrying off as dust the lightest rock flour from the surface, often sweeping the streets clean of loose fragments and depositing dust over nearby houses and vegetation. Thus, the rain and wind, together or singly, are mainly responsible for the loss of that layer of finely ground rock which should constantly cover the top of every road and street a small fraction of an inch in thickness.

The mechanical agencies are the most easily seen, and are chiefly the grinding and pounding of the travel over the highways. The pulverized surface is thereby constantly loosened ready for the wind or rain, and just as fast as this disappears more is worn from the underlying rocks to replace it. Also, if the mass of the road be not well compacted, it will loosen, tending to form "chuck holes." Obviously, the heaviest traffic will do the most damage, and will be the most difficult to meet. The disrupting effect of roots should be reduced to nothing by a proper construction of the road bed.

Keeping these considerations in mind, it can be seen that a choice of road metal is made by considering for every case (1) the requirements which the road must fulfill; and (2) the power of given materials to meet these conditions. In any one locality the mechanical wear and tear is all that varies appreciably, the rest remaining practically constant. In other words, the traffic changes from place to place, so that we need harder and firmer highways in a city than in the open country. These five divisions of traffic are commonly made to denote this: City (perurban), urban, suburban, highway, and country road. City traffic is that existing on the streets of large cities, and no ordinary macadam can withstand it. Stone and wooden blocks, asphaltum, vitrified brick, and some few other substances are commonly used. Urban traffic is that common to city streets not used for continuous heavy teaming. The hardest and toughest macadam must be used, for the wear is heavy. Suburban traffic is, as the name denotes, that found on city streets in their outer limits, and in the main thor-

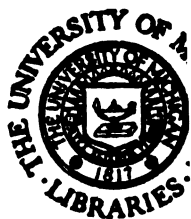
oughfares of country towns. A rock of less hardness and toughness is required. Highway traffic is that found on the main country roads, for which a material of medium qualities should be used. Country road traffic exists on the less used roads in the least settled districts. A comparatively soft rock is needed in these localities. This division of traffic is purely arbitrary, yet of the greatest importance. At first thought it might appear that a rock well fitted for the heaviest traffic would surely be satisfactory for lighter travel. No greater mistake could be made. The two opposed forces: the wear on a road, and the hardness, toughness and binding power of the material used, giving resistance to wear, must actually balance each other to give the highest results in any given case. The road surface, composed of the necessary layer of fine material, must be renewed just as fast as it disappears. In other words, speaking broadly, as fast as the wind and water carry away the materials from the top of a road, just so fast should the under rock fragments grind down under travel to form new surfacing. The amount of work done by the wind and water should be reduced to a minimum by selecting a road metal with maximum binding quality. Then the other qualities of the stone must be fitted to the needs of the travel destined to be over it. If too small a supply of fine surface material, or "binder," be furnished, because of too light traffic for the particular stone used, the road "ravels," and the underlying rock fragments project, making the road rough as well as weak. If too much protecting surface be supplied, from too heavy traffic, the excess results in dust or mud. In a moist climate a thicker layer of surfacing is permissible than in a dry climate.

Having these few fundamental considerations in mind, it is possible to choose a road metal with greater chances of its success. The three main characteristics which must be considered first are hardness, toughness, and binding power. Hardness is the resistance of a rock or mineral to rubbing, as by grinding on an emery wheel, and to force applied to crush the stone. Toughness is the resistance to fracture by blows, as continually delivered upon a road by travel. The cementing power has been explained as due to slight chemical change in the rock. It is also due, in small part, to the mere presence of a little moisture. It is well known how firm wet sand is compared to dry. In all cases, a slight percentage of water in the mass of road material is necessary. There is, naturally, much diversity of opinion regarding the values of the various road materials. A rock suitable in all respects for one locality may easily prove a total failure in another. A stone much

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affected by frost should not be used in a cold region, nor will a brittle one give the best results in a dry climate. It appears to be the consensus of opinion that, all things considered those rocks called popularly "traps" are the best. These rocks are found typically as dykes, hence are intermediate in texture, and are largely diabase and diorite. They are among the toughest of the rocks, and usually have good binding power. The best varieties of these traps make satisfactory roads for urban traffic, but are too hard and tough for the lighter travel. The finer grained plutonic rocks probably come next in order of value, the more basic being the best as a rule, because of better cementing qualities. Granite is often frowned upon, yet some granites have given good results. The presence of hard, but brittle, quartz seems to be the chief objection, while micaceous granites, as well as all rocks containing mica, are unsatisfactory. However, given a binding power in a stone, any ordinary amount of free quartz is of real value, because it is not decomposed under ordinary conditions, and furnishes an unchanging base for the road. The volcanic rocks are of varying values. Basalt blocks are used for paving for city traffic, but for macadam their field is limited. Preference is given the crystalline rocks. Rhyolites, with sufficient binding power, have given excellent results in some localities. Andesites might also make good roads. The crystalline metamorphic rocks, the gneisses and schists have been used with good results. Of the atmospheric rocks, few seem to find favor. In the West, especially in California, such rocks have been largely used, with eminent success. In Golden Gate Park, San Francisco, a dark red chert has furnished material for the excellent roads, which are among the finest in the State. At other points around San Francisco bay, and in the interior valleys, where the climate is much like that of western Nevada, a metamorphic sandstone has made fine roads. Also, a dark basic diorite has been used for heavy traffic with satisfactory results. Limestone would seem on the face of the matter to be almost worthless as a road metal, yet some roads have been constructed of it in the east with great satisfaction. Some varieties are hygroscopic, that is, attract moisture from the air and might prove of service in a dry climate. Here in Nevada, and particularly near Reno, where the construction of stone roads will begin, there are several promising rocks. An immense supply of rhyolite containing considerable iron outcrops less than a mile north of Reno, and an abundance of a medium basic granite, much of it without mica, or with little, exists to the south and west. The latter rock, considering the traffic, might

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(8.) "Earth Roads." Farmers' Bulletin No. 136. Dept. of Agric.

(9.) "The Use of Oil on Roads." Year book of Dept. of Agric., 1902.

(10.) "The Social, Commercial and Economic Phases of the Road Subject." Circular No. 34. Office of Road Inquiry.

(11.) "Going in Debt for Good Roads." Circular No. 26. Office of Road Inquiry.

(12.) "Wide Tires." Bull. No. 12. Office of Road Inquiry.

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CHAPTER VI.

CONCLUSION.

There are a few points to be emphasized and a few explained before bringing this paper to a close. The real need of such publications, incomplete as they must necessarily be in a new and undeveloped State like Nevada, is surely apparent to all progressive citizens. The vast size of the unknown and undeveloped in the State is almost appalling when contrasted with what little is known. And the work of the future, the proper opening up of the State in all possible ways, depends largely upon the methods of its accomplishment. The haphazard stage has been passed, and we must build solidly and scientifically. The bonanzas have been exhausted from the great Comstock, and the future of that famous lode rests upon the scientific mode of attacking the problem now present: that of working immense bodies of low-grade ore at a profit. And with the agriculture of the State, that industry which heretofore lagged behind the rest, the great problems of irrigation are fundamentally connected. Every detail must be worked out scientifically, in accordance with law and order. Likewise with the building stones of Nevada. No order, and little real knowledge has governed the choice and use of materials in the past. No harm has been done, because the needs were few and simple. But with the growth of large towns and cities, new and great buildings will be required, and real scientific facts about the materials of construction available will be needed. And so with many other lines of human activity. We need not only to know, but to know in the right way; to have scientific knowledge, to understand law and truth. It is largely to aid in bringing about the acceptance of such considerations that this paper has been written.

Regarding the subject matter, a few words of explanation seem necessary. First, the rock classification may strike petrographers as rather behind the times. It is, and necessarily so. The tendency of modern petrographic thought is toward the drawing of fine lines, and the classification of rocks in accordance with new ideas and conceptions. This is all necessary and right, but the uninitiated have no use for such terms as "persalane," "dofemic," and the rest. A popular terminology will and must always be distinct from the petrographic, if such names are universally adopted by scientists. The main idea underlying the writing of the chapter on the classification of rocks is this: To convey some definite idea to the practical man re-



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of the general names of rocks, with
pertaining thereto. Very unfortunately, it
that with the advent of more exact petro-
must come more or less of a dual classifica-
terms are good and sufficient for all prac-
no change for these purposes, no
lengths the more exact terminology
they cannot be changed, for obvious
not be forgotten by the scientist in his

the qualities of building stones is complete
of the present paper but will need more
port. The larger facts are, of course, given
of the methods of testing building ma-
d when a final report is issued.

ks themselves, the list brings to light some
to be seen that at present some amounts
that this use is daily increasing. Also it
ening of the State to new and better times,
ne buildings will occur. But the cardinal
little is known definitely about Nevada;
e depends largely upon this knowledge of
in the one small line of building stones,
human activity. This thought should not
nstant.

ad metal is included because it is believed
ormation. Reno must soon lay new streets
f an increasing population, and it will not
f the other large towns follow suit. And
many other engineering works, looks easy.
To the business man, mining appears
hole and taking out ore. Likewise to the
business, road making seems to consist
ot of rock on a road and smoothing it off a
atly in error, and it is high time every good
of the proper construction of roads. And
that it is not always, nor often, that the
least to construct is the cheapest.

stated that all in his short paper has been
f the light coming from the new day of
e of Nevada, with her boundless wealth of
ginning to awaken due appreciation.

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FLUATING-SYSTEM

AT THE

MINES, NEVADA

BY

J. YOUNG

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System at the Comstock Mines, Nevada.

BY GEORGE J. YOUNG,* RENO, NEV.

(Spokane Meeting, September, 1909.)

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I. INTRODUCTION.

CHURCH, in his treatise on the Comstock Lode,¹
clear account of the conditions of the mine

or of Mining and Metallurgy, University of Nevada.

stock Lode: Its Formation and History (1879).

during the period of greatest activity. The difficulties in the way of deep mining at that time were excessive water and high temperature. The drainage of the mines taxed the financial resources of the mining companies, and the high temperatures restricted the capacity of the miners for underground labor. In spite of these difficulties exploratory work was continued until the financial burden of removing the water became too great. The companies then restricted the work to the upper levels. The years 1883 to 1886 marked the period of cessation of deep mining.

For 12 years thereafter mining was confined to the levels above the Sutro tunnel; and, while the question of drainage was more or less agitated, nothing of importance was done until the formation of the Comstock Pumping Association in 1898. Since that time successive levels have been drained until, at present, on the north-end mines, a depth of 700 ft. below the Sutro-tunnel level has been reached. Mining is now carried on in the Ophir mine from the 1,700- to the 2,200-ft. levels, and a winze is being sunk to make connection with the 2,300-ft. level (the 2,450 ft. of the C. & C. shaft).

In 1903 the Ward Shaft Association was formed to undertake the draining of the Central and Gold Hill group of mines, and at the present time a depth of 2,500 ft. has been reached in the Ward shaft. The situation at the Ward looks promising, and the 3,000-ft. level may be reached in the near future. It is proposed to establish a large pumping-station on this level, and then begin the opening of known ore-bodies and the prospecting for new ones.

The main factors which have contributed to the successful solution of the drainage problem are the Sutro tunnel, the use of the hydraulic elevator as a sinking-pump, the concentration of pumping-units, and cheap electrical power.

The question of high temperature and its control still remains as a minor but important problem. The temperatures encountered in the new workings are as great as those in the earlier periods. The Comstock was considered the hottest group of mines in the world, and I am not aware of similar conditions in any other mining-district. A water-temperature as high as 160° F. has been reported from the Ward shaft, and temperatures below the Sutro tunnel are very high in many instances.

cessive underground temperatures is effected by the provision and distribution of sufficient volume. Upon the Comstock of late attention has been paid to ventilation, and conditions have been much improved.

Of metalliferous mines has received but little comparatively few data are available. The literature, on the other hand, is replete with data of the topic being one of considerable interest at the time. In coal-mines, ventilation has for its purpose the removal of explosive gases. To accomplish this is usually employed to force into or exhaust from the mines of air. In metal-mining, while occurrence is not infrequent, the volume of gas encountered is small as to be unimportant, and it is generally in these cases the purpose of the ventilating-current is to supply pure air to the miners in the different workings and to remove the gaseous products of blasting. Ventilation has the ventilating-current to perform the function of cooling the mine-workings. In most cases ventilating-currents are established by the use of up-cast, the other a down-cast. The natural underground-temperature, due to increased depth, is so warm the air sufficiently to start an upward current. When this is attained, the average temperature of the mine is raised and the ventilating-efficiency of an up-cast is lessened. Fans and air-pipes are used for the ventilation of the shafts, and dead-ends, but are seldom used for the ventilation of a large mine. The Comstock is an excellent example of the use of natural ventilation by the provision of a current of sufficient volume partly to overcome the natural conditions. That natural ventilation is not so controllable enough, is evidenced by the fact that at the present time one large fan is in operation and another is being erected. Ventilation by small fans is also very common to supplement the effect of the shafts. The purpose of this is to give a detailed account of the system of ventilation now in use at the Comstock mines.

II. TEMPERATURES.

In any system of natural ventilation, surface and underground temperatures play an important part.

1. *Surface-Temperatures and Conditions.*—Virginia City, Nev., does not possess a meteorological station, and consequently no records of the weather-conditions are available. However, the records of the government station at Reno, 18 miles NW., supply this deficiency. Virginia City has an altitude of between 6,000 and 6,500 ft., and Reno 4,553 ft., above sea-level.

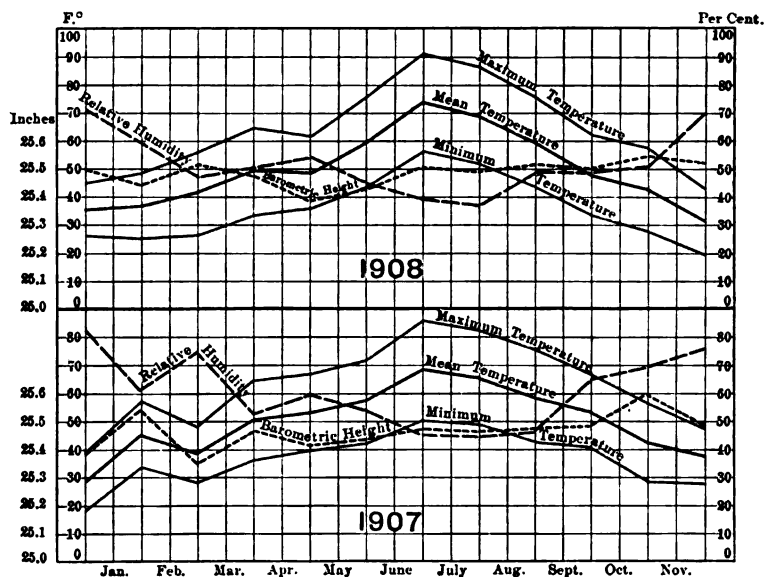


FIG. 1.—CURVES OF MAXIMUM, MEAN, AND MINIMUM TEMPERATURES, RELATIVE HUMIDITY, AND BAROMETRIC HEIGHT, AT RENO, NEV., IN 1907 AND 1908.

The difference in altitude would make some, but not a very great, difference in climatic conditions.

The maximum, mean, and minimum temperatures, the barometric height, and the average relative humidities for the years 1907 and 1908, are plotted in Fig. 1. It should be noted that the day-humidity is much less than the average 24-hr. humidity; for instance, in July, 1907, the average humidity of four days was 28; in August, the average of four days was 19; in September, the average of two days was 21.5; in October, the average of four days was 51; in November, the average of three days was 43; and in December, the average of four days

The average day-humidity during the months of June and September was 21; and for the months of October, November, and December it was 51 per cent. The humidity during the summer and fall months is characterized by its regularity, and during the winter months the day-humidity is normal. The average yearly temperature is

Recorded Temperatures.—Becker² has given excellent data on the temperatures prevailing at different points in the mine, and to this authority the reader is referred. Air-velocity will be considered in this paper.

Records of air-temperature in the Ophir mine have been kept since 1882, and from these records have been compiled the following tables, I., II., III., and IV.

TABLE I.—*Temperatures at Sutro-Tunnel Level.**

Feet South of Connection to C. & C. Shaft.	No. 2, South of Winze.	No. 3, Head of Winze.	No. 4, From Union Connection to Ophir Incline.
Degrees F.	Degrees F.	Degrees F.	Degrees F.
85	102	104	100
90	102	102	100
97	100	104	98
99	100	100	90
92	100	104	.....
94	100	.....	.....
94	98	.....	98
96	.....	.....	.....
96	102	102	96
96	100	.....	.....
97	102	104	97
98	102	105	96

gives the temperatures measured in the north end of the Sutro tunnel during June and July, 1908. The conditions were very favorable during the months of June and July and August, during which the conditions in the Sutro tunnel in the vicinity of the Combination Shaft were particularly trying. No. 1 station in the north end of the tunnel, 100 ft. south of the connection to the C. & C. shaft, showed an average temperature of 91° F. for June and July. Only a feeble air-current was moving towards the south at this station. At No. 2 station, between

* Comstock Lode and the Washoe District, *Monograph III.*, U. S. Geological Survey, 228 to 265 (1882).

the C. & C. shaft connection and the "hot winze," the air was practically dead, and in June the average was 100.3° ; for July it was 101.6° . On July 17, I measured a temperature of 102° at this point. No. 3 station, at the head of the "hot winze," delivering hot air from the workings of the Ophir mine below this level, gave an average June temperature of 102.8° , and for July, 103.3° . No. 4 station, at the connection with the Union shaft, showed an average temperature of 95.2° for June and 96.3° for July. The lowering of the temperature at No. 4 station was due to the cool air from the Union shaft leaking through a canvas curtain and joining the hot air at both the north lateral and the connection to the Union shaft. At stations Nos. 3 and 4 the temperature was measured in a swiftly-moving air-current.

In the Sutro tunnel, south lateral, no temperature-records were available, but observations made by me showed a temperature of 108.9° in the vicinity of the Julia shaft, Dec. 13, 1908; in the Ward shaft connection, 101.1° ; at the junction of the Ward shaft connection and the south lateral, 86° ; at the connection of the Sutro tunnel and south lateral, 100° ; west of the Combination partition, 94.6° , and east of the partition, 93.7° . A temperature has been noted^{*} of 105° for Apr. 15, 1905, in the Sutro tunnel, east of the Combination partition, and during the months of July and August, 1908, this temperature is reported to have prevailed.

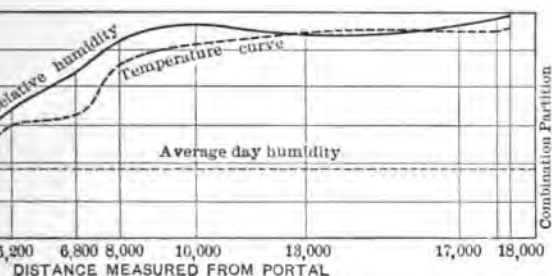
The Sutro tunnel is an incast and, as a consequence, the temperatures vary from a minimum at the portal to a maximum at the Combination partition. This variation was measured, and the results are shown in Table II. The tabulated results are plotted in Fig. 2.

An air-temperature of 46° was raised to 95° in passing a distance of 18,000 ft. The air-temperature in the Sutro tunnel varies with the temperature of the outside air, the temperature of the water passing through, and the rock-temperature. The most important factor is the temperature of the water pumped from the C. & C. and the Ward shafts. This water is passed through both the north and south laterals in 24-in. wooden-stave pipes, and at a point 1,000 ft. east of the Combination partition (approximately 18,000 ft. from the portal) the pipe terminates

^{*} Leon M. Hall and Frederic W. Bishop, *Report to the Comstock Pumping Association* (May 25, 1908).

Variations of Temperature in Sutro Tunnel.

Distance from Portal.	Temperature of Water.	Temperature of Air.	Relative Humidity.	Notes.
Feet.	Deg. F.	Deg. F.	Per Cent.	
Combination partition.	.....	94.5	98.5	
5,000	.....	94.4	98.2	{ Near Combination partition. End of wood pipe.
6,000	95.0	95.0	97.2	
7,000	.....	95.0	93.7	
8,000	93.7	91.9	98.0	Prospect switch.
9,000	92.8	85.2	92	
10,800	90.7	73.0	83	{ Beginning of 30-in. pipe.
11,200	.....	71.6	74	
12,000	.....	46.0	59	
Combina- partition.	.....	93.74	96.4	
14,400	92.5	93.2	100	
15,000	94.1	93.56	97.2	



SHOWING TEMPERATURE AND RELATIVE HUMIDITY
VARIATION IN THE SUTRO TUNNEL.

flows out, occupying about two-thirds and in full width of the tunnel. From the portal a has been constructed a distance of 7,000 ft., point and the former, or a distance of 11,000 ft., the surface of the water. This exposure not but also saturates it with water-vapor. The between the air-temperature and the water-ld be noted.

perature in the south lateral near the Julia shaft temperature more than to water, since in the water is carried in a wooden pipe. The tem-ments in the north and south laterals are II.

TABLE III.—*Temperature-Measurements in North and South Laterals of Sutro Tunnel.*

Date.	Distance.	Temperature of Water.	Temperature of Air.	Relative Humidity.	Notes.
		Deg. F.	Deg. F.	Per Cent.	
Dec. 13, 1908.	Surface, Ward shaft.....		40.1	39.6	7.45 a.m.
Dec. 13, 1908.	1,600-level station.....	.....	88.7	65.5	
Dec. 13, 1908.	Half to south lateral.....	.....	101.1	63.5	
Dec. 13, 1908.	{ Junction south lateral and Ward connection. }	.....	87.8	80.4	
Dec. 13, 1908.	{ South lateral south from charge station. }	.....	86	84.6	
Dec. 13, 1908.	2,300 ft. from tunnel.....	.....	96.8	64.4	
Dec. 13, 1908.	1,550 ft. from tunnel.....	.....	105.8	54.4	
Dec. 13, 1908.	400 ft. from tunnel.....	.....	108.86	55.9	
Dec. 13, 1908.	100 ft. from tunnel.....	.....	104.0	63.8	
Dec. 13, 1908.	{ Sutro tunnel at junc- tion of south lateral. }	.....	100	73.7	
Dec. 13, 1908.	{ Sutro tunnel 100 ft. west of north lateral. }	.....	87.8	91.4	
Dec. 13, 1908.	{ 75 ft. west of Combina- tion partition..... }	.....	94.6	83.9	
Oct. 11, 1908.	{ Outlet of air-pipe near winze, north lateral. }	.....	97.0	46.5	
Oct. 11, 1908.	{ Cross-cut to C. & C. shaft..... }	95.9	93.2	95.0	
Oct. 11, 1908.	{ Just before reaching Mint shaft..... }	.....	91.4	95.0	
Oct. 11, 1908.	{ Junction of Sutro tun- nel and N. lateral.... }	.....	90.9	94.0	

3. *Water-Temperatures in Sutro Tunnel.*—Opportunities for measuring the water-temperature are few and far between. On Oct. 11, 1908, the water discharged from the C. & C. shaft into the tunnel gave a temperature of 95.9° F.; on Dec. 12 the water from the Ward shaft, close to the Ward, gave a temperature of 141.8°. On the same day, at a point 15,000 ft. distant from the Sutro-tunnel portal, the water-temperature measured 94.1°. The water-flow from the C. & C. shaft amounts to from 4,000 to 4,500 gal., and from the Ward, from 600 to 800 gal. per min. In addition, all the water from the ground above the Sutro tunnel drains into the laterals and discharges into the Sutro tunnel. The average temperature of the water flowing into the Sutro tunnel at the Combination partition is between 94° and 95°. Miners say that sometimes this temperature is exceeded.

4. *Temperatures of Mine-Workings.*—The temperatures in the Ophir workings have been observed for some time, and from

*Temperature-Measurements in Different Parts of the
Ophir Mine.*

2,200 Snow- sheds.	2,200 Fan.	2,100 Ophir.	2,100 N. Slopes	2,200 Station.	2,200 Raise.
Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
104	98	98	98	100	111
104	97	98	97	98	110
104	97	97	98	100	111
105	98	98	98	100	110
110	98	98	98	99	111
106	98	98	97	102	111
108	97	98	97	105	113
109	98	98	96	105	112
104	97	98	97	101	112
102	97	96	96	100	111
104	96	97	98	100	110
105	99	98	100	102	112
103	98	101	102	102	110
101	97	100	102	102	109
97	94	97	100	101	110
96	92	96	100	98	108
100	87	95	100	98	108
102	91	97	100	98	108
109	92	99	100	99	109
107	91	96	100	101	109
109	92	96	100	101	108
106	90	95	100	100	108
107	91	95	100	100	108
107	89	94	100	100	108
112	93	91	101	102	108
105	92	94	100	102	108
108	93	96	100	104	108

*Temperature-Readings in Different Parts of Ophir
Mine and on Different Dates.*

2,300 Drift.	2,100 N. Drift.	2,100 Slopes.	2,200 N. E. Drift.	2,200 Slopes.	2,200 Winze.
Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
130	104	103	104	105	106
112	101	102	101	104	103
129	101	102	101	104	102
128	100	101	100	102	102
126	100	101	101	103	101
127	100	101	99	101	101
126	100	101	99	101	100
102	101	104	104	105	102
101	101	102	100	102	100
104	102	103	101	102	100
110	102	102	105	103	100
110	102	105	104	104	101
112	102	103	104	104	102
110	101	103	104	104	102
112	101	104	104	104	101
112	101	102	102	102	101
112	103	102	102	102	102

the daily reports Tables IV. and V. have been compiled. Only a few readings were tabulated, since but very little variation in the temperature takes place from day to day.

From Tables IV. and V. the following averages have been calculated for workings below the Sutro tunnel:

Working-Place.	Average from all Tables.	Average Maximum from all Tables.	Average Minimum from all Tables.
	Degrees F.	Degrees F.	Degrees F.
2,250 station, C. & C.....	67	73.3	62.7
2,200 station, Ophir winze.....	101.2	102.1	100.6
2,150 drift.....	99.2	101.6	95.3
2,250 drift.....	105.6	110.5	101.8
2,350 drift.....	116.9	125.4	108.5
2,100 stopes.....	101.2	103.0	99.0
2,200 stopes.....	103.0	103.2	102.8
2,200 raise.....	109.7	109.7	.....

The temperatures given for the 2,250 and other stations of the C. & C. show the temperatures of the incoming air-currents on the different levels. The measurements in the drifts give the temperatures after the air has been heated to a maximum by contact with the walls of the drifts. A particularly hot zone was passed through by the 2,350 drift close to the 2,350 station of the C. & C. Before connection was made with the Ophir winze, the temperatures were so excessive as to cause the miners much suffering. As soon as a connection was made the temperature dropped about 15°. A progressive increase in temperature with depth is to be noted in the case of the drifts. Few measurements were made at different elevations in the stopes, but the air-current rises in temperature as it ascends in the stope. Confined mine-workings, such as drifts and raises, were usually observed to be the hottest workings, especially where no air-connections exist. Large mine-openings, such as stopes, are usually cooler.

III. THE VENTILATING-SYSTEM IN GENERAL.

A ventilating-current on the Comstock must provide pure air for the miners and a sufficient volume to temper the heat of the underground workings; it must also remove the steam and the gaseous products of blasting. A ventilating-current of sufficient volume to cool the workings enough to be noticeable would meet all the other requirements. The general and consider-

temperature along the lode makes it possible
nts of some volume and velocity by natural
With the exception of the Ward shaft, all
effected by upcast shafts, supplemented by
l distribution of the air in drifts, raises,
. Three shafts, the Ophir, the Combina-
er, are used as upcasts; six shafts, the Union,
int, the old Yellow Jacket, the Overman,
used as down-casts. The Ward shaft is di-
; and one compartment (the pump) is used
er two compartments, in which the hoisting
a down-cast. A fan is attached to the upcast
exhausts the air.

—This shaft takes the air from the workings
the down-cast air coming principally from
The upcast air is taken from a winze in the
y a cross-cut to the Ophir incline, and thence
Ophir shaft. At the foot of the Ophir shaft
s air from old stopes and workings of the
an east cross-cut connects with the Union
from that shaft.

upcast.—This shaft draws air from the Sutro
d west of the Combination partition, which
plit the connection from the Combination
unnel. The down-cast air comes from the
alta shafts. The air from the Union crosses
the Ophir through a 20-in. galvanized-iron
partitions keeping the currents from mixing.
Mint shaft is taken through three lines of
sted by fans, to the Gould and Curry, the
, and the Hale and Norcross workings. It is
ugh the north and south laterals to the Sutro
to the Combination shaft. The air from the
h a long connection and into the south lat-
ection to the Ward shaft. The air east of
artition comes from the Sutro-tunnel portal.

t.—This shaft ventilates the Yellow Jacket,
the Caledonia mines, and draws air for this
old Yellow Jacket and the Overman shaft.
t of upcast air from the three shafts and the

Ward measures 235,835 cu. ft. per min., and the amount of down-cast air measures 216,687 cu. ft. per min. The discrepancy between the two amounts is due to the difficulty of making accurate measurement, of rise in temperature, leakage, variation in the velocity of the air-current at different times, and the accession of water-vapor and gases from the mine-workings. The distribution of the air between the shafts is shown by Table VI.

TABLE VI.—*Distribution of Air in Upcasts, Down-Casts, and the Suro Tunnel.*

Shaft.	Number of Compartments.	Area.	Quantity.	Temperature at Collar.	Temperature at Level.	Connecting Level at Bottom.	
		Sq. Ft.	Cu. Ft. per Min.	Deg. F.	Deg. F.		
Combination.....	4	129	51,651	87.6	95.2	1,600	Yellow Jacket
Ophir.....	4	94	58,454	88.9	98.8	1,600	
Belcher.....	3	60	31,706	73.9	87.3	1,100	
Ward.....	1	33	94,024	67.5	104	2,475	
Total upcast air..	12	316	235,835				
C. & C.....	3	77.3	28,941				
Union.....	4	126	13,814				
Yellow Jacket...	3	64.2	10,665				
Alta.....	2	43.3	13,364				
Mint.....	1½	30	7,500				
Overman on } 900-ft. level.. }	3	60	5,981				
Unaccounted } for in Belcher }			15,060				
Suro tunnel.....	1	63	27,339				
Ward shaft.....	2	55	94,024				
Total down- cast air.....	19½	518.8	216,687				

From Table VI. the average velocity in feet per minute has been calculated as follows:

	Cu. Ft. Per Min.
Whole upcast area,	746.3
Whole down-cast area,	417.6
Whole upcast area, excluding Ward shaft,	501.1
Whole down-cast area, excluding Ward shaft,	264.4

An interesting comparison with past conditions is afforded by the data given by Church.⁴ Table VII. is quoted from his treatise.

⁴ *The Comstock Lode: Its Formation and History*, p. 18 (1879).

Distribution of Upcast Air, July 2, 1877.

	Quantity.	Temperature of Up- cast at Top of Shaft.
	Cu. Ft. per Min.	Degrees F.
.....	4,000	.....
.....	7,700	76
.....	21,600	84
.....	48,750	89
y.....	12,000	.....
.....	58,500	100
.....	18,000	77
.....	10,080	89.5
idated.....	28,800	95
.....	52,200	89
.....	27,000	93
.....	288,630	Aver. temp.....88.05

as down-casts, but were not named. Church quantity of air as a minimum, and states 00 cu. ft. represents the average amount of 0 cu. ft. per min. as the quantity of air due rs in use. The outside temperature for the e measurements were made is given as

unt of air per upcast, from Table VII., is n., and temperatures at the top of the shaft cluding the Ward shaft, Table VI. shows 0 cu. ft. per min. per shaft, and a top-tem- 83.4°. The figures indicate a somewhat e upcast shafts at the present time than in r average temperature shows the effect of ings. The fewer upcast shafts and the of the present time would indicate, on the istance to the movement of the air than at ade his studies. The greater effectiveness ast shafts could be explained by the more fans. No detailed data are available con- small fans during the early periods of the e shafts mentioned by Church, only the nd Overman are open, and of these the n are used as down-casts, while the Belcher present time.

relation of the underground workings, the d down-cast shafts.

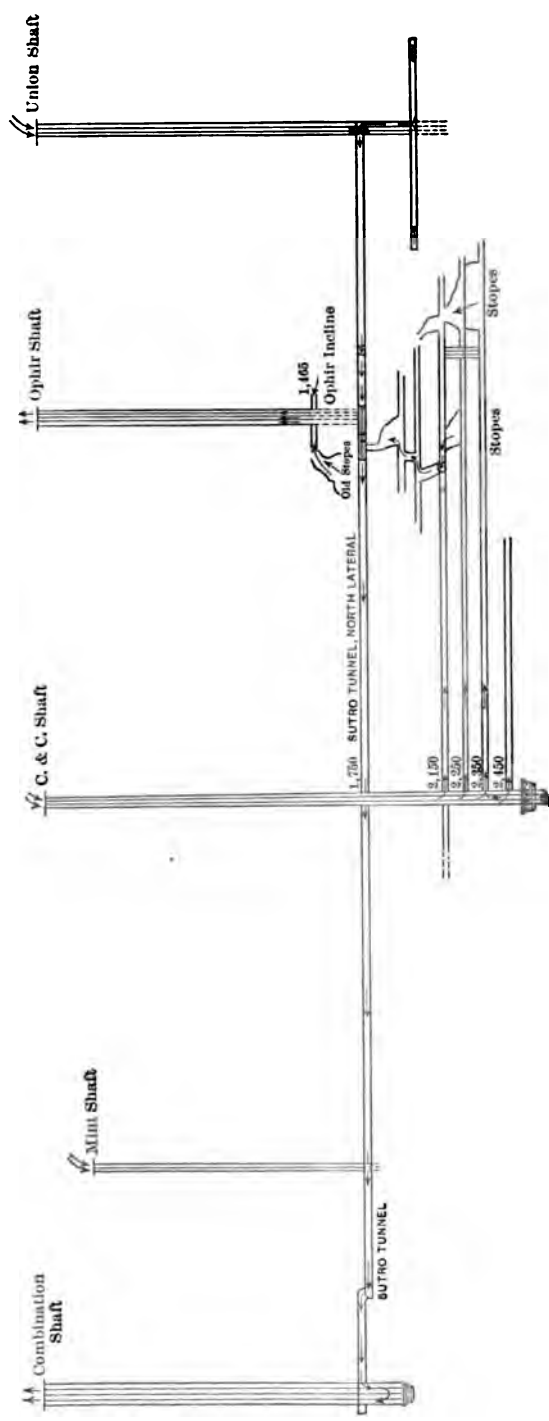


FIG. 3.—LONGITUDINAL SECTION, SHOWING WORKINGS AND SHAFTS OF NORTH-END MINES.

VENTILATING-SYSTEM IN DETAIL.

The down-cast air is taken to the 2,000-ft. means of a 15-in. air-pipe to a fan 600 ft. cross-cut. It is then forced to the face of and also to the face of the south drift, dis- f 500 and 1,000 ft. The discharges are re- 796 cu. ft. per min. The combined dis- ft. per min. With an inflow at the Union per min., the delivery is 42.9 per cent. of urns through the east cross-cut to the shaft through the pump-compartment, which is Sutro-tunnel level, and then through a long uth lateral and also to the connection lead- ft. The north lateral takes 4,086 cu. ft. remainder, 9,728 cu. ft. per min., finds its upcast. The average temperature on the 3.3° F., and on the Sutro-tunnel level it ue to the fact that a comparatively large wn-cast air leaks past the air-pipe on the goes up the pump-compartment, cooling the Union workings. The portion of air ination shaft traverses 12,061 ft. from sur- portion passing up the Ophir moves 7,680 ft. n the distribution of the air on the Sutro- ble VIII. gives the measurements made on

e.—The down-cast air in the C. & C. shaft s—one split on the 2,150-ft. level, an air- ft. per min.; one on the 2,250-ft. level, an ; one on the 2,350-ft. level, of 11,667, and level, which was not measured.

level the air is taken through the drift to a e shaft, then picked up by a fan and forced and down through that connection to the 200-ft. level of the Ophir. The fan takes in., and the difference, 1,635 cu. ft., leaks n and joins the upcast air.

level part of the air is taken by a fan at the down to the 2,350-ft. level to ventilate the

TABLE VIII.—*Measurements of Air, Temperatures, and Relative Humidities at the Suto-Tunnel Level.*

Section.	Date, 1906.	Velocity.	Area Section.	Quantity.	Temperature.	Relative Humidity.	Notes.
		Ft. per Min.	Sq. Ft.	Cu. Ft. per Min.	Deg. F.	Per Cent.	
F.	Dec. 28.	228	63	13,364	84.2	86.2	Air from Alta shaft.
F.	Dec. 13.	161	63	10,134	86.0	84.6	Air from Alta shaft.
G. & C.	Nov. 15.	1,159	1.23	1,426	65.2	71.0	To Gould and Curry through 15-in. pipe.
G. S.	Nov. 15.	904	2.66	2,404	65.2	71.0	To Savage through 15- in. pipe.
H. & N.	Nov. 15.	2,452	1.39	3,408	65.2	71.0	To Hale and Norcross through 15-in. pipe.
G. & C.	Dec. 28.	1,122	1.23	1,380	63.1	77.8	To Hale and Norcross through 15-in. pipe.
G. S.	Dec. 28.	886	2.66	2,357	63.1	77.8	To Hale and Norcross through 15-in. pipe.
H. & N.	Dec. 28.	2,706	1.39	3,761	63.1	77.8	To Hale and Norcross through 15-in. pipe.
T.	Dec. 13.	1,085	8.1	8,221	87.8	91.4	Through door.
Winze.	July 15.	980	20.0	19,600	107.6	100—	Mine air.
J.	July 16.	650	39.0	25,336	105.4	100—	Curtain at N. closed.
J.	July 16.	488	39.0	16,454	105.4	.....	Curtain at N. open.
J.	July 17.	600	39.0	23,400	104	97	Curtain at N. closed.
J.	July 17.	329	39.0	12,831	104	.....	Curtain at N. open.
J.	Oct. 11.	567	54.5	30,901	93.2	95	Partition at N.
J.	Dec. 12.	874	39.0	30,186	99.0	81.2	Partition at N.
J.	Dec. 29.	940	35.0	32,780	100.4	76.4	Partition at N.
K.	July 15.	1,060	29.7	31,482	101.3	100—	Curtain at N. closed.
K.	July 16.	1,108	29.7	32,907	100.4	100—	Curtain at N. closed.
K.	July 17.	730	35	25,550	98.6	97.9	Curtain at N. closed.
K.	July 17.	809	35	28,315	95.0	.....	Curtain at N. open.
M.	July 16.	484	35	16,440	105.8	.....	Air from old stopes.
M.	July 17.	330	35	11,550	104.9	.....	Air from old stopes.
L.	July 16.	210	20	4,200	93.2	.....	Air from Union shaft.
L.	July 17.	145	20	2,900	95.9	.....	Air from Union shaft.
R.	July 15.	190	56	10,640	91.4	.....	.....
R.	July 16.	190	35	6,650	87.8	.....	Curtain closed at N.
R.	July 16.	376	35	13,160	87.8	.....	Curtain open at N.
R.	July 17.	120	35	4,200	88	73.4	Curtain closed at N.
R.	July 17.	221	35	7,735	85.8	.....	Curtain open at N.
R.	Dec. 12.	3,291	0.4	1,316	86.4	66.8	Air-pipe in partition.
N.	Dec. 12.	384	22.4	8,143	82.4	72.4	Curtain removed.
O.	Dec. 12.	278	14.72	4,086	82.4	72.4	Air going to I.
P.	Dec. 12.	109	31.00	3,379	82.4	72.4	.....
Q.	Dec. 12.	478	24.85	13,814	82.4	70.3	.....
H.	Oct. 11.	1,632	2.07	3,378	97	46.5	20-in. pipe.
H.	Dec. 29.	1,750	2.07	3,622	94	48.0	20-in. pipe.
I.	Oct. 11.	1,750	2.00	3,500	93.6	49.0	20-in. pipe.

east drift; the remainder, amounting to 14,521 cu. ft. per min., passes into the drift until it reaches a stope, where two fans pick it up, one forcing the air past the stope into the Consolidated Virginia workings, the other forcing the remaining air down through the Ophir winze to the 2,200-ft. level of the Ophir mine. The Consolidated Virginia fan (No. 3) takes 3,323 cu. ft. per min., while the Ophir fan (No. 2) takes 11,566 cu. ft. per min. Beyond the stope another fan (No. 1) takes air from the Ophir-winze station and forces it on to the stopes north of the Ophir winze. This air rises up through the stopes and event-

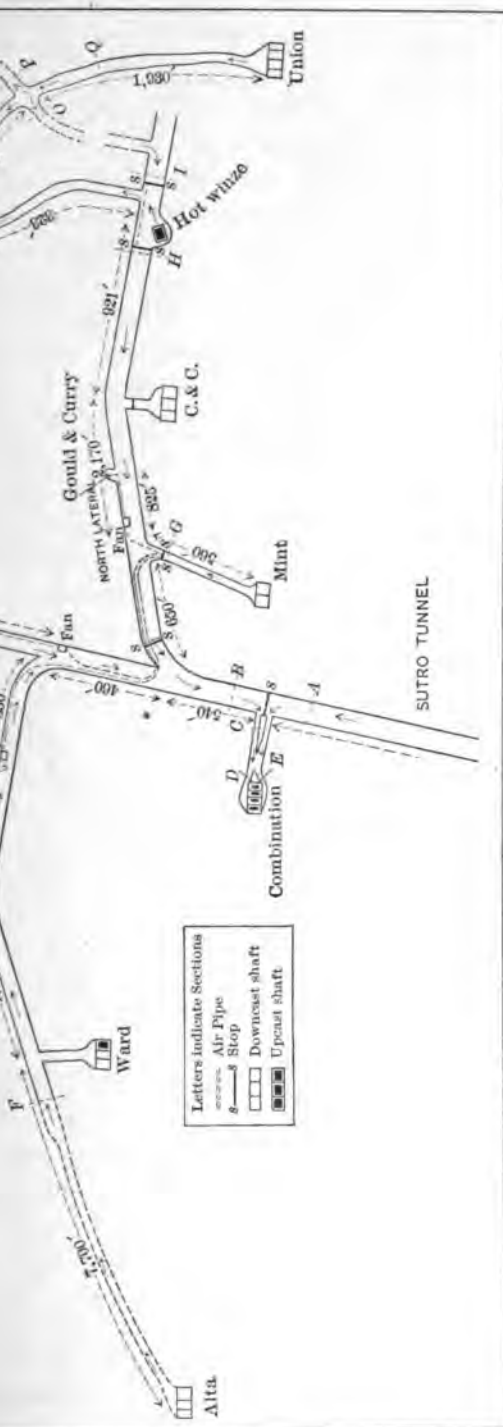


FIG. 4.—PLAN SHOWING DISTRIBUTION OF AIR ON SUTRO-TUNNEL LEVEL.

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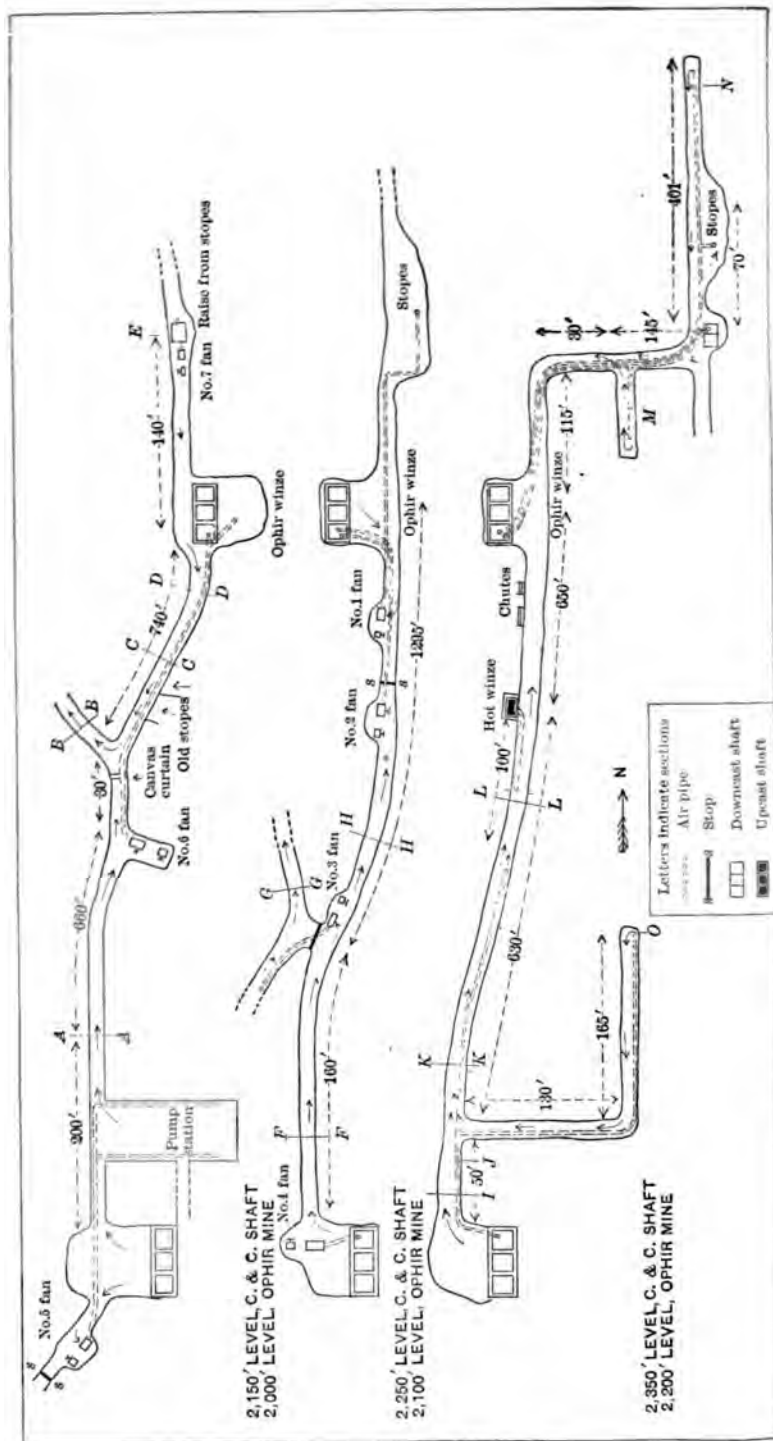


FIG. 5.—PLAN OF 2,000- 2,100- AND 2,200-FT. LEVELS OF THE OPHIR MINE.

in the "hot winze" of the north lateral.
cu. ft. per minute.

550-ft. level passes through the main drift,
the fan on the 2,250-ft. level passes into a
t east of the main drift, returns, and joins
ugh the main drift towards the Ophir winze.
ures, noted previously, were taken in this
nection was made. The average tempera-
on was 125.4° , and some months later the
ed 100.4° . The lowering in temperature
eased volume of air and to the boarding-up
the sides and top of the drift, which very
hot water, steam, and much of the heat
ock-surfaces.

l is ventilated by a No. 8 cast-iron Ameri-
ir is taken through an inlet-pipe extending
ompartments of the shaft and forced to the
east cross-cut, returning through the cross-
not in operation at the time of my visit. On
er of flooding this level the fan was driven
engine.

y of air in the three main splits amounts to
in., and this compares closely to the 32,760
a the same day on the Sutro-tunnel level.
ans of the three levels of the Ophir mine,
which velocity-measurements were made.
are given in Table IX.

ry Mine.—At the Sutro tunnel a west cross-
. This is ventilated by an air-pipe and fan
n the Mint shaft. The inflowing air at the
2 cu. ft. per min. (1,159 cu. ft., November 15).
es this air to the fan, and from the fan an 11-
th the cross-cut, distant 189 ft. The air dis-
989 cu. ft., or 88.1 per cent. of the inflow.
use.

An east cross-cut is being run in the Savage
5 ft. above the Sutro tunnel, which also re-
Mint shaft. A 15-in. air-pipe takes 2,404
a fan 1,110 ft. distant in the Sutro tunnel,
ges through a 15-in. pipe to the top of the

TABLE IX.—Air-Measurements at Different Sections in Ophir Mine.

Date, 1906.	Level.	Section.	Area.	Velocity.	Quantity.	Temperature.	Relative Humidity.	Notes.
			Sq. Ft.	Ft. per Min.	Cu. Ft. per Min.	Deg. F.	Per Cent.	
July 15. 2,000		A.	29.75	240	7,140	97.2	96.5	
Dec. 29. 2,000		A.	31.50	223	7,024	87.4	34.2	
July 15. 2,000		No. 6 fan.	1.77	2,766	4,896	-----	-----	Velocity low.
Dec. 29. 2,000		No. 6 fan.	1.77	3,045	5,389	98.6	37.5	Inlet of fan.
July 15. 2,000		B.	29.75	480	14,280	116.6	100—	Air to upraise to Sutro tunnel.
Dec. 29. 2,000		B.	23.22	620	14,396	108.1	86.7	Air to upraise to Sutro tunnel.
July 15. 2,000		C.	28.05	175	4,900	112.3	45.4	
Dec. 29. 2,000		C.	26.00	156	4,056	105.8	58.8	
Dec. 29. 2,000		D.	25.6	434	11,110	107.6	59.1	
July 15. 2,000		E.	20	225	3,875	100	98.5	
July 15. 2,100		F.	29.75	397	11,810	76.1	95.4	
Dec. 29. 2,100		F.	31.5	461	14,521	64.8	93.3	
July 15. 2,100		G.	26	320	8,320	96	89	
Dec. 29. 2,100		No. 3 fan.	2.82	1,182	3,323	-----	-----	
July 15. 2,100		H.	29.75	280	8,330	82.4	79.8	
Dec. 29. 2,100		H.	30.9	284	8,776	90.1	55.3	
Dec. 29. 2,100		No. 2 fan.	7.01	1,650	11,566	90.1	55.3	
Dec. 29. 2,100		No. 1 fan.	1.67	2,270	3,791	100.4	49.7	Temperature taken at Ophir-winze station.
July 15. 2,200		I.	28.25	220	6,140	89.6	96.4	Connection made.
July 15. 2,200		J.	1.22	3,492	4,160	82.4	-----	End of 15-in. air-pipe; air from No. 4 fan.
Dec. 29. 2,200		K.	28.25	413	11,667	84.2	88.4	
Dec. 29. 2,200		L.	-----	-----	-----	96.6	96.8	End of snow-sheds.
Dec. 29. 2,200		Hot winze	-----	-----	-----	102.7	93.8	
Dec. 29. 2,200		-----	-----	-----	-----	104	96.8	50 ft. south of Ophir winze
Dec. 29. 2,200		{ Ophir winze. }	-----	-----	-----	100.4	45.8	
Dec. 29. 2,200		O.	1	1,996	1,996	89.6	40.6	Air from pipe, No. 4 fan.
Dec. 29. 2,200		M.	1.22	606	739	102.2	48.5	Air from pipe, No. 1 fan.
Dec. 29. 2,200		N.	1.11	490	544	104.5	36.5	Air from pipe, No. 1 fan.
Dec. 29. 2,200		-----	-----	-----	-----	98.6	72.6	Slopes between 2,100- and 2,200-ft. levels.

raise and then by an 11-in. pipe to the working-face, 180 ft. distant from the top of the raise. The discharge measures 894 cu. ft. per min., or 37.1 per cent. of the inflow. The section of 11-in. pipe caused the most leakage. The fan was in operation at the time.

5. *Hale and Norcross Mine.*—The Hale and Norcross receives air from the Mint shaft. A 15-in. air-pipe leads to the H. & N. connection in the south lateral, 1,460 ft., and from this point a fan takes the air and forces it to the H. & N. and Chollar cross-cuts, distant 325 ft.; 11-in. branch-pipes take the air to the working-faces, 190 ft. to the H. & N. and 122 ft. to the Chollar. The H. & N. discharge measures 941 and the Chollar 934 cu. ft. per min. The combined discharge measures 1,875 and the inflow at the Mint 3,761 cu. ft. per min. The discharge is 49.8 per cent. of inflow. The measurements of both the Chollar and the H. & N. are given in Tables X. and XI. and Fig. 6.

Air-Measurements in Hale and Norcross and Chollar Mines.

Quantity.	Temperature.	Relative Humidity.	Notes.
Cu. Ft. per Min.	Deg. F.	Per Cent.	
3,408	65.2	71	Nov. 15, 1908. } Air going into
3,761	63.1	77.8	Dec. 28, 1908. } H. & N. air-pipe.
934	104.5	23.8	Nov. 15, discharge of 11-in. pipe.
.....	105.1	61.4	{ Dec. 28, discharge at J, 78 ft. from B.
721	106.2	22.0	Dec. 28, discharge of 11-in. pipe.
.....	97.5	69.0	Nov. 15.
.....	104.0	51.2	Dec. 28.
941	106.1	21.8	Nov. 15, discharge of 11-in. pipe.
.....	107.6	32.2	{ Face of drift 12 ft. from end of pipe, Nov. 15.
688	109.4	20.0	Discharge of 11-in. pipe, Dec. 28.
.....	109.6	29.8	{ Face of drift 25 ft. from end of pipe, Dec. 28.
.....	95.5	66.2	Nov. 15.
108	81.7	51.4	{ Leakage, 15-in. damper; cooling bench, Nov. 15.
3,350	104.0	24.8	{ Damper on split closed; F open, Dec. 28.
1,890	104.0	24.8	Both dampers open, Dec. 28.
.....	104.0	24.8	Damper at F closed, Dec. 28.
.....	98.1	64.4	Nov. 15.
.....	100.4	62.5	Dec. 28.
.....	105.8	66.6	Nov. 15.
.....	108.1	62.7	Dec. 28.
.....	105.5	58.5	Nov. 15.
.....	104.0	63.8	Dec. 13.
.....	108.86	55.9	Dec. 13.

Flow and Discharge of Air at Hale and Norcross and Chollar Mines.

	Discharge.	Air Lost.	Quantity Delivered.	Distance.
Min.	Cu. Ft. per Min.	Cu. Ft. per Min.	Per Cent.	Ft.
	1,983	1,425	58	2,137
	1,409	2,352	37.4	2,155
	3,350	411	89	1,730

—The Sutro tunnel is an incast air-way and way on the Comstock. A plan of the tunnel partition is shown in Fig. 7. The air enters at the Combination partition, passes to the Combination partition,

a distance of 18,700 ft.; then through the connection to the Combination shaft, a distance of 400 ft., and then to the surface, a distance of 1,600 ft. vertically. The total distance is 20,700 ft. This Combination shaft also serves to draw air from the workings west of the Combination partition. The average quantity of air from the east is 27,339 cu. ft. per min. (average of four observations at different times); from the west it is 29,961 cu. ft. per min. (average of four observations at different times); and the total average passing to the Combina-

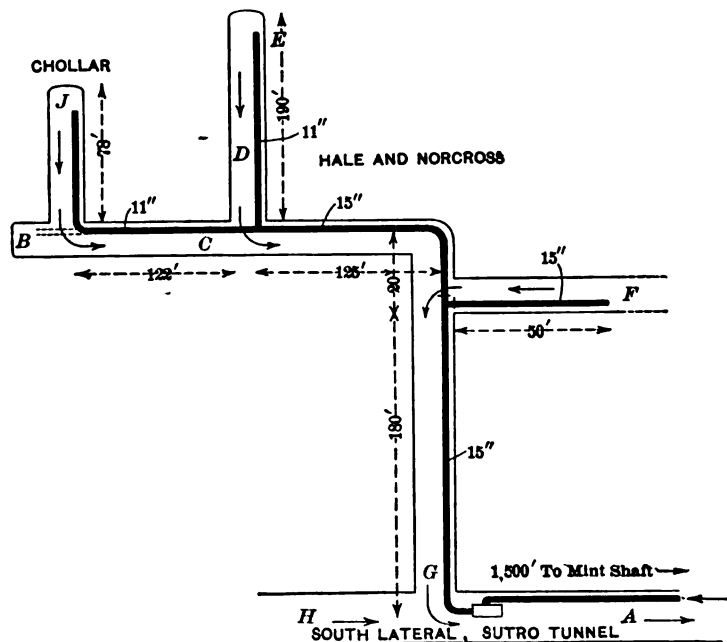


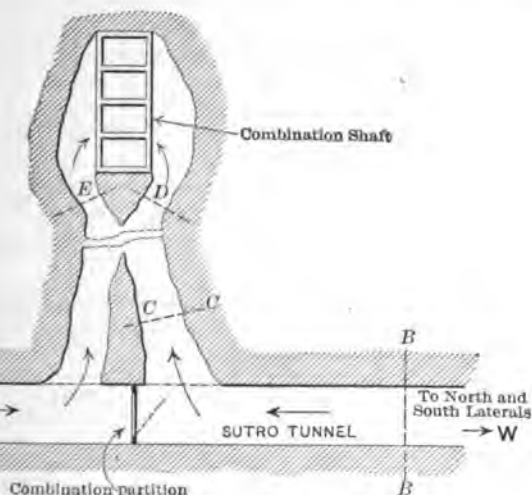
FIG. 6.—PLAN OF CHOLLAR AND HALE AND NORCROSS WORKINGS.

tion from both directions measures 57,300 cu. ft. per min. The observations made at the Combination partition are tabulated in Table XII.

An interesting comparison is afforded by a measurement made in the Sutro tunnel, Mar. 7, 1909. The Sutro tunnel just west of the Combination partition was completely blocked by a cave, and the Combination shaft drew air only from the east side. The quantity of air measured 30,124 cu. ft. per min.; temperature, 89.6° F.; relative humidity, 100 per cent. The temperature at the foot of the shaft measured 92.8°; relative

Observations on Air-Currents at the Combination Partition.

Velocity.	Area.	Quantity.	Temperature.	Relative Humidity.	Barometer.	Time.
per in.	Sq. Ft.	Cu. Ft. per Min.	Deg. F.	Per Cent.	In.	
730	35.72	26,075	94.3	96	.....	11.20 a.m.
850	27.58	23,443	95.4	95.4	.....	11.20 a.m.
154	18.9	21,810	95.54	85.7	.....	11.20 a.m.
492	48.5	23,813	97.52	93.0	.....	11.20 a.m.
523	48.5	26,500	95.0	100	25.4	.....
631	48.5	32,181	94.5	98.4	25.15	9.00 a.m.
604	48.5	30,200	93.7	96.4	25.10	10.00 a.m.
480	48.5	24,000	94.1	96.4	25.35	11.00 a.m.
527	46.3	29,307	95.5	85	25.4	.....
732	46.3	33,891	95.2	83.9	25.1	9.00 a.m.
628	46.3	29,076	94.64	83.9	25.15	11.10 a.m.
594	46.3	27,572	94.50	83	25.39	11.00 a.m.



SUTRO TUNNEL AT COMBINATION PARTITION.

cent.; barometer, 25.15 in. A measure-
the same date, within 2 hr. of the measure-
at the collar of the Combination shaft, and
n. at a temperature of 72°; relative humid-
and barometric height, 23.85 in., was the
es show a pronounced cooling-effect of the
volume of air passing, and this would de-

crease the efficiency of the shaft as an upcast. Instead of obtaining a greater volume of air by turning the full effect of the upcast shaft upon the tunnel, only a small increase resulted. This is a direct result of the decreased efficiency of the shaft.

A recording-anemometer was placed in the Sutro tunnel close to the Combination partition, and three 24-hr. records taken of the east air. The observed velocities are tabulated in Table XIII., the average velocities in Table XIV., and the quantities of air in Table XV. The anemometer was placed in the position shown in Fig. 8. The ratio between the average velocity for the section and the velocity for the position was determined by measurements with the small anemometer. This ratio was found to be 1.12, and this figure was used in reducing the observed velocities. The area of the section is 48.5 sq. feet.

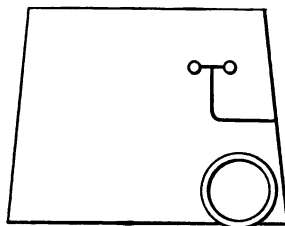


FIG. 8.—SECTION OF SUTRO TUNNEL EAST OF COMBINATION PARTITION, SHOWING POSITION OF ANEMOMETER.

TABLE XIII.—*Velocity-Readings.*

Time.	Nov. 21 to 22, 1908.	Nov. 22 to 23, 1908.	Nov. 23 to 24, 1908.	Time.	Nov. 21 to 22, 1908.	Nov. 22 to 23, 1908.	Nov. 23 to 24, 1908.
	Miles Per Hr.	Miles Per Hr.	Miles Per Hr.		Miles Per Hr.	Miles Per Hr.	Miles Per Hr.
12 to 1 p.m.	.....	.....	.....	1 to 2 a.m.	5.00	4.70	5.60
1 to 2 p.m.	.....	3.90	.....	2 to 3 a.m.	5.00	4.80	5.50
2 to 3 p.m.	.....	3.75	.....	3 to 4 a.m.	4.20	4.62	5.90
3 to 4 p.m.	4.25	4.40	4.90	4 to 5 a.m.	4.34	4.75	5.50
4 to 5 p.m.	4.00	4.30	5.40	5 to 6 a.m.	3.90	5.13	5.50
5 to 6 p.m.	4.33	4.20	5.20	6 to 7 a.m.	4.16	4.80	5.40
6 to 7 p.m.	4.30	4.50	5.00	7 to 8 a.m.	4.55	4.80	5.74
7 to 8 p.m.	4.30	4.44	5.00	8 to 9 a.m.	4.62	5.00	5.45
8 to 9 p.m.	4.30	4.64	5.20	9 to 10 a.m.	4.60	4.80	5.40
9 to 10 p.m.	4.47	4.34	5.25	10 to 11 a.m.	4.28	4.20	5.30
10 to 11 p.m.	4.93	4.50	5.55	11 to 12 a.m.	4.50	4.10	5.30
11 to 12 p.m.	5.07	4.55	5.64	12 to 1 p.m.	4.25	4.20	4.60
12 to 1 a.m.	5.13	5.10	5.38	1 to 2 p.m.	.....	4.00	.....

TABLE XIV.—Average Velocities.

Maximum.		Minimum.		Time, Maximum.	Time, Minimum.
Miles Per Hr.	Ft. Per Min.	Miles Per Hr.	Ft. Per Min.		
5.75	505.2	4.37	384.4	12 to 1 a.m.	5 to 6 a.m.
5.75	505.2	4.37	384.4	5 to 6 a.m.	1 to 2 a.m.
6.61	581.3	5.16	453.4	3 to 4 a.m.	12 to 1 p.m.
6.04	530.6	4.63	407.4	.....	.....

velocities have been plotted in Fig. 9.

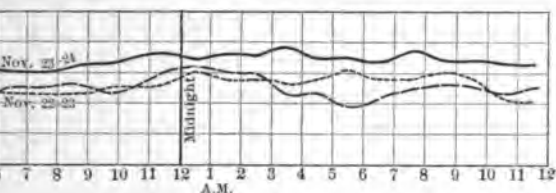


FIG. 9.—RELATION BETWEEN VELOCITY AND TIME OF DAY.

TABLE XV.—Air in Cubic Feet Per Minute.

Average Quantity of Air.	Maximum Quantity of Air.	Minimum Quantity of Air.
Cubic Feet.	Cubic Feet.	Cubic Feet.
21,257	24,502	18,859
19,846	24,502	18,859
25,564	28,193	21,990
22,222	25,732	19,903

quantity, as shown in Table XV., and all the exception of one, are lower than the average from the readings in Table XII. Maximum velocities do not occur at any particular time. The character of the velocity-curves is noteworthy, and is the fact that at several points in the tunnel are in for some little distance, and the added friction of these results in more or less of a pumping-effect. It is, therefore, a more delicate recording-instrument than the larger waves to be formed of a multitude of smaller waves. The movement of cars in the tunnel does not have any decided effect upon the curves, although measuring-instruments might have shown it.

at Mine.—Three levels of this mine are open

and operated from the old Yellow Jacket shaft. On the first level, the 900-ft., the air entering measures 3,075 cu. ft. per min. The air passes through a drift and thence down a winze to the 1,000-ft. level. The temperature and relative humidity of this air-current, at a point 500 ft. from the shaft, measured 66.2° F. and 55.6 per cent. respectively. The second, or 1,000-ft. level, receives 3,030 cu. ft. per min. from the shaft. Part of this air is taken by an air-pipe and conducted a distance of 350 ft. to a raise on the foot-wall of the vein, returns, joins the remainder, and then passes down through old stopes to the 1,100-ft. level.

The third, or 1,100-ft. level, is closed by a door in the drift, so as to force the air down the incline, which heads at this level, into an old station which is being reopened. The air escapes up through old stopes to the 1,100-ft. level. All the air passing down the Yellow Jacket shaft is brought together in the south drift, passes through a cross-cut to the old Belcher incline, and thence to the surface through the Belcher shaft. The amount of air passing through the drift measures 10,665 cu. ft. per min. The 900-ft. level of the Overman and Caledonia, corresponding to the 1,100-ft. of the Yellow Jacket, delivers 5,981 cu. ft. per min. to the Belcher shaft. The total quantity of air measured on this level is 16,646 cu. ft. per min., while the average passing up the Belcher is 31,706, leaving unaccounted for 15,060 cu. ft. per min. This comes from the lower levels of the Overman and Caledonia, but no measurement was possible at the time. The Yellow Jacket air at the foot of the Belcher incline gave a temperature of 79.7° and a relative humidity of 68 per cent.; the air coming from the Overman a temperature of 82.4° and a relative humidity of 62.3 per cent.

8. *Ophir and Belcher Upcasts.*—The measurements of both these shafts are to be found in Tables XVI. and XVII.

9. *Combination Shaft.*—The measurements for the Combination shaft are given in detail in Table XVIII. The numbered circles in Fig. 10 indicate the position in which the anemometer was held for each measurement.

Table XIX. has been calculated from the data of Tables XVI., XVII., and XVIII.

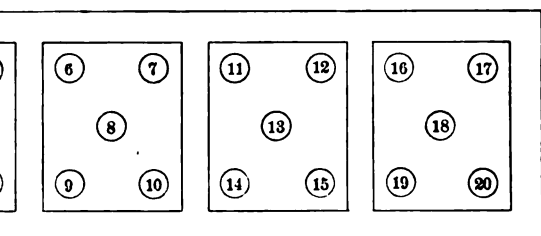
Since the cooling of the upcast air directly affects the effi-

Air-Measurements in Ophir Upcast Shaft.

No. 2.	No. 3.	Average.	Quantity.	Shaft-Temperature.	Relative Humidity, Shaft.	Surface-Temperature.	Relative Humidity, Surface.	Barometer.
			Cu. Ft. per Min.	Deg. F.		Deg. F.		
99	636	660	62,040	90.5	100 +	73.4	30.45	24.2
96	480	506	47,564	.....	100 +	81.0	16.40	24.2
33	506	523	49,162	98.4	100 +	87.8	18.40	24.0
95	759	630	59,220	89	100 +	40.0	.....	23.8
91	747	721	67,774	89	100 +	45.0	61.2	23.7
98	706	653	61,382	86	100 +	40.6	26.5	23.97
92	675	660	62,040	86	100 +	48.3	50.1	24.0
.....	.....	622	58,484	88.9	100 +	.....	.....	.....

Air-Measurements in Belcher Upcast Shaft.

No. 3.	Average.	Quantity.	Shaft-Temperature.	Relative Humidity, Shaft.	Surface-Temperature.	Relative Humidity, Surface.	Barometer.
		Cu. Ft. per Min.	Deg. F.		Deg. F.		
97	323	595	27,720	.....	100 +	.....	.....
12	525	598	80,611	.....	100 +	.....	.....
17	525	667	86,375	74.3	100 +	50	.....
24	405	655	33,915	74.0	100 +	50	.....
11	586	561	28,714	73	100 +	26.6	24.2
13	323	543	82,992	74.8	100 +	44.6	50.2
.....	603	31,706	73.9	.....	.....	.....	23.9



ON OF COMBINATION SHAFT, SHOWING POSITION OF ANEMOMETER.

st shaft, the factors contributing to this are
ce. I reached the following conclusions:
he difference between the temperature of the
e rock-temperature, the greater the cooling-

ne temperature of the air entering the bottom
greater the cooling-effect of the shaft.

TABLE XVIII.—*Air-Measurements in Combination Shaft.*

Velocity, Feet per Minute.

Date, 1908.	Pump.						No. 1.					
	1.	2.	3.	4.	5.	Average.	6.	7.	8.	9.	10.	Average.
July 16....	110	315	330	200	405	272	312	400	312	350	570	389
Oct. 10....	180	280	300	370	420	306	440	300	.....	622	270	488
Nov. 14....	560	500	452	500	510	504	630	520	.....	630	363	601
Nov. 15....	436	453	459	445	490	456	612	485	.....	622	402	525
Nov. 21....	436	453	459	445	490	456	612	485	.....	622	402	525
Dec. 27....	206	304	320	320	222	274	518	438	.....	526	286	442

Date, 1908.	No. 2.						No. 3.					
	11.	12.	13.	14.	15.	Average.	16.	17.	18.	19.	20.	Average.
July 16....	520	465	560	340	380	453	450	510	560	330	275	425
Oct. 10....	.....	.....	.....	.....	.....	411	350	370	600	410	422	430
Nov. 14....	510	515	.....	530	418	494	520	590	620	406	615	549
Nov. 15....	540	470	.....	310	400	430	464	600	600	390	560	523
Nov. 21....	.....	.....	.....	.....	.....	556	479	617	638	490	584	561
Dec. 27....	548	374	465	367	272	345	461	429	485	312	403	418

Cubic Feet of Air per Minute.

Date, 1908.	Pump C.	No. 1.	No. 2.	No. 3.	Total.	Average Velocity.
July 16....	10,472	11,670	13,590	13,750	49,482	385
Oct. 10....	11,781	14,640	8,220	12,900	47,551	434
Nov. 14....	19,404	12,240	9,880	16,470	57,994	514
Nov. 15....	13,590	14,424	8,600	15,690	52,309	476
Nov. 21....	17,556	12,600	11,120	16,830	58,111	524
Dec. 27....	10,549	10,608	10,350	12,540	44,047	370
Average..	13,892	12,697	10,293	14,696	51,582	450

Date, 1908.	Time.	Temperature, Shaft-Collar.	Relative Humidity, Shaft.	Surface- Temperature.	Relative Humidity, Surface.	Barometer.
July 16....	10.00 a.m.	Deg. F. 80.6?	Per Cent. 100+	65.3	Per Cent. 29.9	In. 24.35
Oct. 10....	.....	.....	100+	.....	.....	.....
Nov. 14....	3.30 p.m.	88	100+	50.0	.....	23.92
Nov. 15....	3 to 4 p.m.	89	100+	52.9	33.8	23.90
Nov. 21....	3.00 p.m.	89	100+	42.8	65.0	23.70
Dec. 27....	1.30 a.m.	84.2	100+	46.0	54.0	24.00
Nov. 16....	2.00 p.m.	87.0	100+	61.0	.....	24.00
Nov. 17....	3.00 p.m.	88.0	100+	64.0	.....	24.00
Nov. 18....	3.00 p.m.	88.0	100+	55.0	.....	23.80

TABLE XIX.—*Relation Between Depth of Shaft and Cooling of Air-Current.*

Shaft.	Tem- perature at Foot.	Tem- perature at Collar.	Depth of Shaft.	Loss in Tempera- ture.	Loss in Tempera- ture, per 1,000 Ft. Depth.	Loss in Tem- perature, per 1,000 Cu. Ft. Air.	Loss in Tem- perature, per 1,000 Sq. Ft. Rubbing- Surface Per Min.
	Deg. F.	Deg. F.	Ft.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
Ophir	102.1	88.9	1,600	13.2	8.25	0.22	0.06
Belcher.....	81.0	73.9	1,200	7.1	6.00	0.22	0.07
Combination.	95.1	87.6	1,600	7.5	4.70	0.145	0.02

Average temperature of upcast air, { Ophir, 95.5°.
 Belcher, 77.4°.
 Combination, 91.35°.

the velocity, and consequently the smaller the area of the upcast shaft, with given area and rubbing-surface, the cooling-effect of the shaft.

The proportion of rubbing-surface to shaft-area, and the cooling-effect.

The upcast air are conducted through the shaft, and the cooling-effect of the incast upon the upcast air

The effect of humidity upon the cooling-effect of the shaft. The conclusion was reached.

The anemometer used in the Sutro tunnel was of the shaft, but no very satisfactory results were obtained. The failure of the instrument to operate in a horizontal position. A special fan to operate in a horizontal position and connected with the recording part of the instrument by means of bevel-gears. The instrument was placed in the up-compartment of the Combination shaft, and the air was drawn by means of small anemometers, and three of the results are given in Tables XX., XXI., and XXII. A factor 0.84 was used in reducing the velocities of the instrument to average velocities for the shaft. The average velocity was determined by taking the average values of the average velocity and center velocity.

The results from Table XX. are plotted in Fig. 11. The characteristics are the same as those of the Sutro tunnel, with the difference that the irregularities are more pronounced. The "pumping-action" of the shaft, due to the irregularities, is shown. The shaft is of uniform section, and the air is drawn to the bottom narrows down to about one-half of both branches of the Sutro tunnel on the Combination partition.

In Tables XVIII. and XXII., the average quantity of air drawn is greater by 9,513 cu. ft. per min. for the 24-hr. measurement than for the average of the single measurements. The average minimum 24-hr. measurement compares favorably with the average of the results shown by the single measurements. This result is to be expected, for the reason that the 24-hr. measurement marks the period of the minimum velocities. The single measurements were made in the

TABLE XX.—*Air-Velocity Measurements, Combination Shaft.*

Observed Velocities, Miles per Hour.

Time.	Nov. 14 to 15.	Nov. 16 to 17.	Nov. 17 to 18.
4 to 5 p.m.	6.20	5.35	5.80
5 to 6 p.m.	5.50	5.50	5.35
6 to 7 p.m.	6.70	6.10	5.60
7 to 8 p.m.	6.70	6.30	5.80
8 to 9 p.m.	6.30	6.30	5.80
9 to 10 p.m.	6.70	6.30	5.95
10 to 11 p.m.	6.30	6.30	6.10
11 to 12 p.m.	5.80	6.30	5.60
12 to 1 a.m.	6.30	6.10	6.70
1 to 2 a.m.	6.70	6.70	6.30
2 to 3 a.m.	6.70	6.30	6.20
3 to 4 a.m.	6.80	.....	6.30
4 to 5 a.m.	6.70	5.80	6.70
5 to 6 a.m.	.....	6.70	5.80
6 to 7 a.m.	.....	6.70	6.80
7 to 8 a.m.	6.30	6.10	6.10
8 to 9 a.m.	6.10	5.80	5.60
9 to 10 a.m.	5.80	5.80	5.80
10 to 11 a.m.	5.80	5.35	5.80
11 to 12 a.m.	5.80	5.80	5.35
12 to 1 p.m.	5.60	5.35	5.80
1 to 2 p.m.	4.80	5.35	5.35
2 to 3 p.m.	.....	5.35	5.10
3 to 4 p.m.	.....	6.10	5.50

TABLE XXI.—*Average Velocities Over Shaft Section.*

Date, 1908.	Average Velocity.		Maximum Velocity.		Minimum Velocity.		Time of Maximum Velocity.	Time of Minimum Velocity.
	Miles per Hour.	Feet per Minute.	Miles per Hour.	Feet per Minute.	Miles per Hour.	Feet per Minute.		
Nov. 15 to 16...	5.67	547.1	5.71	549.7	4.03	388.8	3 to 4 a.m.	1 to 2 p.m.
Nov. 16 to 17...	5.03	485.3	5.53	533.6	4.49	433.3	1 to 2 a.m.	12 to 3 p.m.
Nov. 17 to 18...	4.87	469.9	5.71	549.7	4.28	413.9	6 to 7 a.m.	2 to 8 p.m.
Average.....	5.19	500.7	5.65	544.3	4.26	412.0	1 to 7 a.m.	1 to 8 p.m.

TABLE XXII.—*Volume of Air in Cubic Feet per Minute.*

Date, 1908.	Average.	Maximum.	Minimum.	Shaft-Temperature.	Shaft-Humidity.	Surface-Temperature.	Barometer.	Time.
				Deg. F.	Per Cent.	Deg. F.	In.	
Nov. 15 to 16.....	66,745	67,063	47,441	89	100+	52.9	23.9	Nov. 15, 3 p.m.
Nov. 16 to 17.....	59,210	65,098	52,734	87	100+	61.0	24.0	Nov. 16, 2 p.m.
Nov. 17 to 18.....	57,330	67,063	50,498	88	100+	64	24.0	Nov. 17, 3 p.m.
				88	100+	55	23.8	Nov. 18, 3 p.m.
Average.....	61,095	66,408	50,224	88	100+	58.5	23.9	

ery Ventilation.—At the Ward shaft a No. 200 quarter housing, vertical-discharge, suction 50-h.p. induction motor, is used to ventilate the shaft; and, as sinking is the only work, one of the pump-stations, practically the full power is used for this work. The incast air passes through the testing-compartments, and is deflected in part down at the 2,475-ft. station (pump-station). The deflection is of the width of the compartment, and is suspended by the upper edge from a wall-plate on a level with the top of the compartment. The lower edge hangs loose over the guard-rail of the compartment. This gives a curved surface

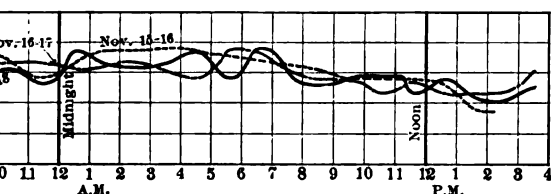


FIGURE 10. SHOWING RELATION BETWEEN OBSERVED VELOCITIES AND TIME OF DAY, COMBINATION SHAFT.

is used to ventilate the station, while allowing the air to sink down, to sweep it out of the way. The air passes down to the sump and then rises through the testing-compartments, which is bratticed off from the main compartments.

The velocity of the fan was measured several times. Five readings were taken in the discharge section, and the average of these readings was taken as the discharge velocity. The following are the results.

On Nov. 13, at the 2,475-ft. level, the temperature in the down-cast compartments was 91.4° F., the relative humidity 93.6 per cent.; in the upcast compartments at the same level the temperature was 104° and the relative humidity 100 per cent. plus. The upcast air was saturated with vapor.

The effect of the fan is supplemented by the chimney effect of the shaft. Calculating this effect, and not allowing for the brattice, a suction of 1.93 in. of water would leave 2.07 in. as the effect of the

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TABLE XXIII.—*Air-Measurements of the Ward-Shaft Fan.*

Date, 1908.	1.	2.	3.	4.	5.	Mean Velocity.	Cu. Ft. Per Min.
July 19.....	2,842	4,200	3,556	2,842	3,576	3,476	105,280
Aug. 8.....	2,248	3,860	3,464	2,280	3,292	3,028	91,597
Nov. 22.....	2,760	3,428	3,044	2,628	2,944	2,959	89,510
Dec. 13.....	2,360	3,552	3,272	2,552	3,272	3,002	90,810
Mean	2,456	3,613	3,260	2,486	3,169	2,996	90,639

NOTE.—Only the last three readings were averaged, as the anemometer was not calibrated for the first reading.

Date.	Fan Discharge.		Air.		Time.
	Temperature.	Relative Humidity.	Temperature.	Relative Humidity.	
	Deg. F.	Per Cent.	Deg. F.	Per Cent.	
July 19.....	.....	.....	.....	.....	9.00 a.m.
Aug. 8.....	90.0	37.0	88.34	14.0	9.00 a.m.
Nov. 22.....	59.0	90.4	36.7	74.9	7.30 a.m.
Dec. 13.....	55.4	94.3	36.5	56.5	12.50 a.m.

Water-gauge on suction side of fan gave 4 in. of water.

fan. The catalogue-rating of the fan is given as 75,700 cu. ft. per min. at 189 rev. per min. and an expenditure of 53.3 h.p. This would give, by difference, 14,939 cu. ft. per min. as due to chimney-draft. Calculation shows the chimney-effect to be equivalent to 17,088 cu. ft. per min. The difference between these two results is undoubtedly due to the catalogue-rating of the fan, which can be taken only in a very general way.

At the Ophir shaft a B. F. Sturtevant No. 16, double width, multi-vane fan is being installed. This fan is rated to deliver 140,000 cu. ft. per min. against a maintained suction of 2 in. of water at a speed of 200 rev. per min. with an expenditure of 100 horse-power.

The plan of the fan-arrangements at the Ward shaft is shown by Fig. 12 and at the Ophir by Fig. 13.

The distribution of the fans underground is given in Figs. 4 and 5, and the details of the fans in Table XXIV. The total horse-power of all motors used for ventilating purposes is 315; of this 150 is used on the surface and 165 underground. The actual horse-power in use, excluding the Ophir fan, which is being installed, is approximately 163.2. Of this 54 is used on

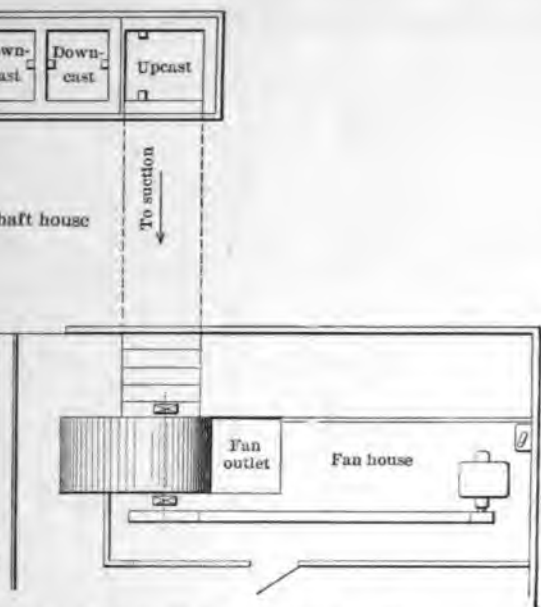


Fig. 12.—PLAN OF FAN AT WARD SHAFT.

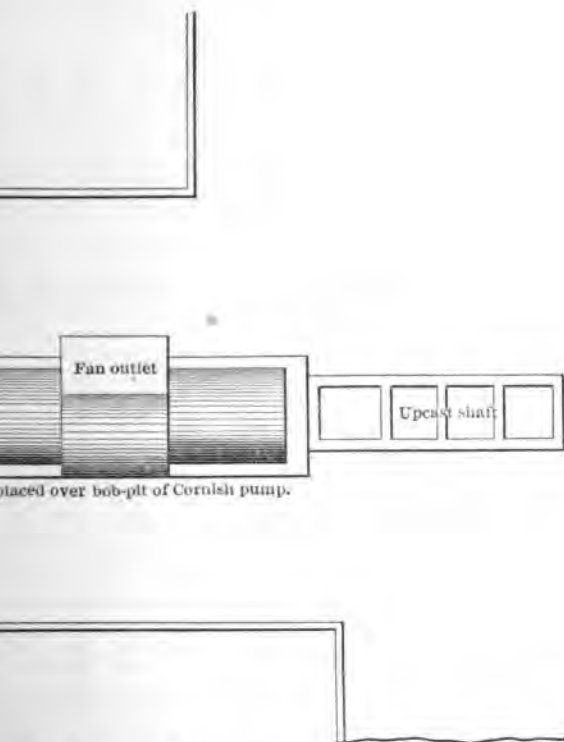


Fig. 13.—PLAN OF FAN AT OPHIR UPCAST.

TABLE XXIV.—Fans in Use on the Comstock.

Position.	Fan.	Motor.	Horse-Power.	Speed.	Air.	Diameter of Inlet.	Area of Inlet.	Diameter of Outlet.	Area of Outlet.	Diameter of Fan-Wheel.	Width of Fan-Wheel.	Notes.
				Rev. per Min.	Cu. Ft. Per Min.	In.	Sq. ft.	In.	Sq. ft.	ft.	in.	
Ward shaft.....	No. 200 metal exhauster.....	H.P. 50	.....	200	90,689	76	31.5	.....	31.25	10	47	
Ophir shaft.....	No. 16 double mine-fan.....	100	.....	200	140,000	70	53.4	.....	53.8	6	7 ft. 4 in.	
Hale and Norcross, Suto tunnel.....	15-in. metal exhauster.....	10	6	1,400	3,761	15	176 sq. in.	15	162 sq. in.	22	12.75	
Savage mine, Suto tunnel.....	15-in. metal exhauster.....	10	6	1,000	2,357	15	176 sq. in.	15	162 sq. in.	22	12.75	
Gould and Curry, Suto tunnel.....	15-in. metal exhauster.....	10	6	1,000	.....	15	176 sq. in.	15	162 sq. in.	22	12.75	{ Not in operation.
Ward pump-station, 2,475 level.....	15-in. metal exhauster.....	5	2	.....	.....	15	176 sq. in.	15	162 sq. in.	22	12.75	{ Suction and exhaust.
Union, 2,000 level.....	15-in. metal exhauster.....	10	8	1,680	4,287	15	176 sq. in.	15	162 sq. in.	22	12.75	
Ophir, No. 1 fan.....	15-in. metal exhauster.....	15	4	1,000	3,791	15	176 sq. in.	15	162 sq. in.	22	12.75	
Ophir, No. 2 fan.....	6-ft. wooden fan.....	20	24	515	11,566	29	1,009 sq. in.	20 by 20	400 sq. in.	72	20	
Ophir, No. 3 fan.....	4-ft. wooden fan.....	5	4	360	3,823	20	406 sq. in.	16 by 16	256 sq. in.	52	16	
Ophir, No. 4 fan.....	6-ft. wooden fan.....	15	9.6	340	.....	29	1,009 sq. in.	20 by 20	400 sq. in.	72	20	
Ophir, No. 5 fan.....	6-ft. wooden fan.....	20	16	500	.....	29	1,009 sq. in.	20 by 20	400 sq. in.	72	20	
Ophir, No. 6 fan.....	15-in. metal exhauster.....	20	14.4	1,500	5,389	15	176 sq. in.	15	162 sq. in.	22	12.75	{ Not in operation.
Ophir, No. 7 fan.....	15-in. metal exhauster.....	.....	.....	.....	.....	15	176 sq. in.	15	162 sq. in.	22	12.75	{ Not in operation.
2,150 Ophir, north workings.....	4-ft. wooden fan.....	5	1.2	360	.....	20	406 sq. in.	16 by 16	256 sq. in.	52	15	
1,000 level, Yellow Jacket.....	15-in. metal exhauster.....	10	.....	1,000	.....	15	176 sq. in.	15	162 sq. in.	22	12.75	
Overman-Caledonia.....	15-in. metal exhauster.....	10	.....	1,860	4,900	16	201 sq. in.	16	201 sq. in.	201	.....	

0-5,200.....	7.21	4.13	7,200	12,000	32,181	450	71.4	35	2.01	43.8	30,533
5,200-6,800.....	7.29	4.08	7,200	12,000	32,181	450	71.4	35	2.01	87.2	25,949
6,800-8,000.....	11.79	4.90	7,200	12,000	32,181	450	71.4	35	2.04	206.9	144,326
8,000-10,000.....	13.23	3.44	7,200	12,000	32,181	450	71.4	35	2.04	94.9	66,200
10,000-13,000.....	16.05	0.82	7,200	12,000	32,181	450	71.4	35	2.04	13.1	10,533
13,000-17,000.....	16.64	0.39	7,200	12,000	32,181	450	71.4	35	2.04	8.1	6,650
17,000-18,000.....	16.99	0.35	7,200	12,000	32,181	450	71.4	35	2.04	10.3	13,463
18,000-18,700.....	17.09	0.10	7,200	12,000	32,181	450	71.4	35	2.04	7.9	8,734
0-18,700.....	17.09	15.01	18,700	634,000	32,181	450	71.4	35	2.04	44.0	30,693
Ward S. connection, Dec. 13, 1908.....	11.147	3.037	2,720	89,760	10,143	161	63	33	1.90	20.59	14,863
50 feet S. of H. & N. fan.....	14.184	10.481	921	30,383	3,378	54	63	33	1.90	69.89	48,755
North lateral partition.....	4.948										
C. & C. shaft connection.....	15.429										

Drifts.

2,350 west drift, section K.....	84.2	11.00	530	12,190	11,667	413	25.25	23	1.23	561.4	391.62
2,350 west drift, near winze.....	98.6	18.77	165	3,877	1,996	63	31.5	23.5	1.34	55.8	38.923
2,350 east drift, end of pipe.....	97.3	7.74	660	15,510	7,024	223	31.5	23.5	1.34	39.2	27.845
2,350 east drift, turn of drift, C.C.....	97.4	4.68									
2,350 N. drift, section A.....	98.5	7.123									
No. 6 fan.....											

Shafts.

C. & C. surface.....	38.5	0.868	1,900	82,650	33,212	431	77	43.5	1.77	74.17	51,789
C. & C., 2,150.....	59.7	3.944	900	33,750	10,665	166	64.2	37.5	1.71	51.76	35,106
Yellow Jacket, surface.....	24.7	1.036	2,000	134,000	13,814	109.6	126	67	1.88	30.4	21,906
Yellow Jacket, 800 level.....	49.6	3.760									
Union S., surface.....	46.8	0.766									
Union S., 2,000 level.....	65.1	5.688									

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the surface and 109.2 underground. With the Ophir fan in use the total horse-power approximates 263.2.

11. *Air-Pipes*.—The extensive use of air-pipes warrants a detailed description.

The air-pipe is in 12-ft. lengths, 11-in. and 15-in. diameter being commonly used. No. 20 galvanized iron, in sheets 36 in. wide, cut to the necessary lengths for the diameters required, and with longitudinal seams punched, is delivered to the mine shop and there made into pipe as required. Longitudinal seams are riveted with $\frac{3}{16}$ -in. rivets, 2.5-in. pitch; girth seams, 4-in. pitch. Longitudinal and girth seams are soldered. Joints are made with a bell, which is riveted and soldered to the pipe. Laps are 0.75 to 1 in. The mouth of the bell is strengthened with $\frac{3}{16}$ -in. wire. The diameter of the mouth is 16 in. and the depth 4 in., not including the lap. This gives an over-all length of 12 ft. for each section.

The bell-joint is known as the "Southwell" joint. Elbows are made with an 18-in. radius, measured to the center of the pipe, and are provided with a bell-joint; the inside diameter of the mouth is 15.5 in.; the outside, 16.25 in. Rivets on transverse joints are pitched 2.5 in., and on longitudinal joints 1.5 in. Six pieces, including the bell, are required for each joint. The opposite end of the elbow has a diameter of 15.75 in. Right-angle tees, used for branches, are provided with two 11-in. dampers, having a clearance of $\frac{3}{8}$ in., and 15-in. dampers with a clearance of from $\frac{1}{8}$ to $\frac{1}{4}$ in. The dampers are riveted to a flattened $\frac{5}{8}$ -in. iron rod, one end of which is bent so as to form a 6-in. handle. The damper is cut in the blacksmith-shop from $\frac{1}{8}$ -in. sheet iron. Elbows of 45° are made from three pieces, including the bell. "Y" pieces and special breechings for the fans are made as required; 20-in. pipes, occasionally used, are made from No. 18 or No. 20 galvanized sheet-iron, with longitudinal seams riveted on 2.5-in. pitch, and girth seams from 5 to 6.75-in. pitch. The inside diameter of the bell-mouth is 20.75 in.; the outside, 21.25 in.; and the depth of the bell is 5 inches.

Air-pipes are suspended by U-shaped iron straps, made from $\frac{3}{8}$ - and $\frac{1}{2}$ -in. round iron, each end of the U being provided with a 3-in. point. The straps are driven into the timbers, three straps to each 12-ft. section. Where the air-pipe is placed

lifts, it is suspended by ropes or wire from drilled holes, or else from sprags wedged to which the iron strap-points are driven.

are made tight by wrapping several times as strip 7 in. wide. Six or seven wrappings of cord are used to hold the canvas in place. ly wrapped in the manner described, allows leak through at the joints. Data on leakage in this paper.

om acid mine-waters, and not battered by of an air-pipe is indefinite; but in wet shafts to acid waters they frequently have to be re-

of 15-in. air-pipe is \$8.50 per section; the cost nominal. The placing of a 15-in. air-pipe 5 per section, or \$0.77 per linear foot.

ge.—Leakage depends very largely upon the pping the joints. If the ends are much battered may be considerable. Pressure and velocity or factors.

at air-pipe extends from the Mint shaft to the workings. Connection is made with a fan 500 ft. from the shaft. The discharge from tance of 230 ft., showed a loss of 411 cu. ft. delivery of 89 per cent. of the inflowing air. t is 2.93 cu. ft. per min. A water-gauge at owed a pressure into the air-pipe of $\frac{13}{16}$ in. of the pipe, 267 ft. of 15-in. and 268 ft. of in all, gave an additional leakage of 1,941 The pipe was not well wrapped, and the loss es out 44.1 cu. ft. per min. In this case the y the fan undoubtedly reduced the leakage ection.

teral of the Sutro tunnel 120 ft. of 20-in. air-akage of 122 cu. ft. per min., or 12.2 cu. ft. pipe was not wrapped, but was very carefully

nd Curry mine a leakage in 825 ft. of 15-in. measured 437 cu. ft. per min., or 6.4 cu. ft. ion. The pipe was partly wrapped and the ured $\frac{13}{16}$ in. The fan was not in use.

In the Savage workings, with fan in operation and 15-in. air-pipe, the leakage amounted to 1,610 cu. ft. per min. The length of 555 ft. of 15-in. pipe beyond the fan and 180 ft. of 11-in. pipe gives a leakage of 26.4 cu. ft. per min. per section. In this case most of the leakage took place on the last 180 ft. of 11-in. pipe.

Dampers showed a variable leakage, depending upon the perfection of the fitting and the care used in closing. Measurements showed from 10 to 180 cu. ft. per minute.

Two canvas curtains were measured: one showed a leakage of 1,635 cu. ft. per min. over an area of 35 sq. ft.; the other, 3,980 cu. ft. per min. over an area of 20 sq. feet.

The general conclusion is that leakage can be controlled within narrow limits by carefully wrapping the joints. A mile of 15-in. pipe with a leakage of 2.93 cu. ft. per min. per section would give a total leakage of 1,289 cu. ft. per min., and with an inflow of 4,000 cu. ft. per min. a delivery of 67 per cent. of the air is possible. This would be more than sufficient to ventilate an ordinary working-face. It is not always desirable to have a pipe tightly wrapped up to the face. Mr. Higginson informed me that with pipe tightly wrapped the blasts, if heavy, will cause much loss by collapsing. The practice is to wrap the pipe up to within from 200 to 300 ft. of the face and then leave the remainder unwrapped. Old and battered pipe is used close to the face.

Stops are constructed from timber or canvas; 1-in. rough boards, battened, are commonly used; doors are made from the same material; clay is used to stop small cracks and openings.

V. MEASUREMENT OF VENTILATING-CURRENTS.

1. *Temperature.*—The mine-measurements were made with an ordinary Fahrenheit thermometer of good grade. The instrument was suspended from a timber, and in approximately the center of the air-way. Unfortunately, this thermometer was not available for calibration. My observations were made with chemical thermometers carefully matched and compared.

2. *Velocity.*—All upcast shafts are housed in by wooden chimneys, which conduct the air outside the shaft-houses. Access to a shaft is had through doors, and from them most of the section may be reached. Five measurements were made in

in each compartment. The center and four positions selected, as shown by the numbering, fig. 10. The corner position was taken 1 ft. each way. The anemometer was held stationary, and the velocity determined over a ranging from 0.5 to 2 min. Observed velocity determined by the calibration-curve furnished by the instrument. Measurements were not taken by instrument over the whole section on account of reaching some of the compartments. In during which measurements were made no work was done in the shafts, but during the remainder shaft-work in all three upcasts. The housing of the anemometer prevented eddy-currents, and consequently measurements were made in the plane of the shaft-collar. Time required to make from 15 to 20 separate measurements varied from 30 to 50 min. Table XVIII. Table of observations for the Combination

Air was measured in one shaft only and at one of the down-cast shafts work was going on. Measurements experienced on account of eddy-currents, even the anemometer was held some distance below the

velocity of each compartment generally exceeded the surface velocity. The ratio between the two was calculated as 1.19 obtained for the Combination, 1.09 for the Ophir shaft, and 1.19 for the Belcher shaft. The reciprocal of this was used to calculate average velocities from the surface velocities. As an example of the use of this method in determining the average velocity, the following is given: The Ophir shaft was measured by both methods in 1908. The average of five readings for each of the four positions was 653, 652 and 675 ft. per min., and the center position was 688, 732 and 732. Computing from these figures and the constant 0.84, the following results were obtained: The average velocity was 651 ft. per min. The average velocity was 660, and the calculated velocity 664 ft.

taken in straight portions of the drifts where-

ever these were available, and timbered sections were used in preference to the untimbered, but no special steps were taken to prepare sections of uniform cross-section. The anemometer was slowly moved over the whole section for a period varying from 0.5 to 2 min. Duplicate readings were generally taken.

On the whole, the measurement of the air in the air-ways of a mine, without special provision for smooth sections, is approximate only, and it is not possible to make very accurate measurements without resorting to extreme measures. My measurements were made during the working-hours of the mines, and without special provision for smooth sections.

The anemometers were of the Biram type, one 4-in. reading to 1,000 ft., one 4-in. reading to 100,000 ft., and one 6-in. reading to 1,000 ft. The recording-anemometer was a Julien P. Friez instrument, of the type used at the government meteorological stations. A sling-psychrometer was used in determining humidities, and the psychrometric tables published by the U. S. Weather Bureau were used in reducing results.

VI. COST AND OPERATING-EXPENSE.

It is almost impossible to obtain detailed figures on the cost of the ventilating-system, but fairly accurate estimates may be made. The following estimate was made by taking the cost of motors and fans and adding 20 per cent. for cost of installation. The 15-in. air-pipe in place was estimated as \$0.77 per ft. and 11- and 20-in. proportionally:

Cost of supplementary ventilating-plant:

Motors,	\$6,000
Fans,	6,000
Air-pipe,	10,000
	\$22,000

NOTE.—The above does not include the cost of the fan and pipe in the Overman and Caledonia mines, nor the cost of electrical conduits.

Depreciation, maintenance, and operating-expense:

Depreciation and maintenance assumed as 10 per cent. of plant-cost, or \$2,200 per annum, or per month, . . . \$183.30

Operating-cost:

Power: 165 h.p., at \$5 per h.p. month,	825.00
1 electrician, at \$4 per day,	120.00
Incidentals,	50.00

Total expense per month, \$1,178.30

NOTE.—Shift-bosses and miners take immediate charge of fans and motors, and no extra men are employed except the electrician.

maintaining the upcast shafts may be proportional to the cost of ventilation, and this is a large part of the cost. No figures are available. During the past year from four to six men have been employed in all three upcast shafts for periods of from one to three months. On an average this work has to be done

rough estimate of expenses per month, the cost of ventilation of air passing through the mines is \$0.00116, and the cost of repair of upcast shafts.

II. UNDERGROUND HUMIDITY.

Air entering during the day is of low and in winter of high humidity. The temperature is neither too low nor high. The greater heat of summer is compensated for by the lower humidity, while the higher humidity of the winter months is compensated for by the lower temperature. The temperature of the entering air is of more moderate humidity. The air-current begins to rise and absorb moisture as soon as it enters the mine workings. How rapidly it changes depends upon the velocity of the air-current, the difference of temperature between the air-current and the surrounding rocks, the relative exposure of the air-current to moisture. The factors may best be studied from the three following

Tunnel.—Table II. and Fig. 2 are referred to. The temperature of the incast air reaches a maximum at a short distance from the portal. The temperature of the water is constant. Humidity begins to increase as the air enters the tunnel. For the first 6,800 ft. the air is in contact with the drainage-water, and condensation of moisture must come mainly from the walls.

Moisture from this source is 43.8 grains per cubic foot of exposed surface per hour. Much of this part of the moisture is absorbed. At the 6,800-ft. station the air comes in contact with the drainage-water, and absorbs moisture until it reaches a point 10,000 ft. from the portal, or after traveling a distance of only 3,200 ft. The exposed water-surface is 19,200 sq. ft. (average width

of stream taken as 6 ft.). On the basis of the exposed water-surface the rate of accession of water-vapor is 798.5 grains per square foot per hour. The rapidity with which the air takes up moisture is remarkable. The rates for different parts of the tunnel have been calculated and are to be found in Table XXV. The total exposed surface, both rock walls and water, has been taken in calculating the table in preference to the water-surface

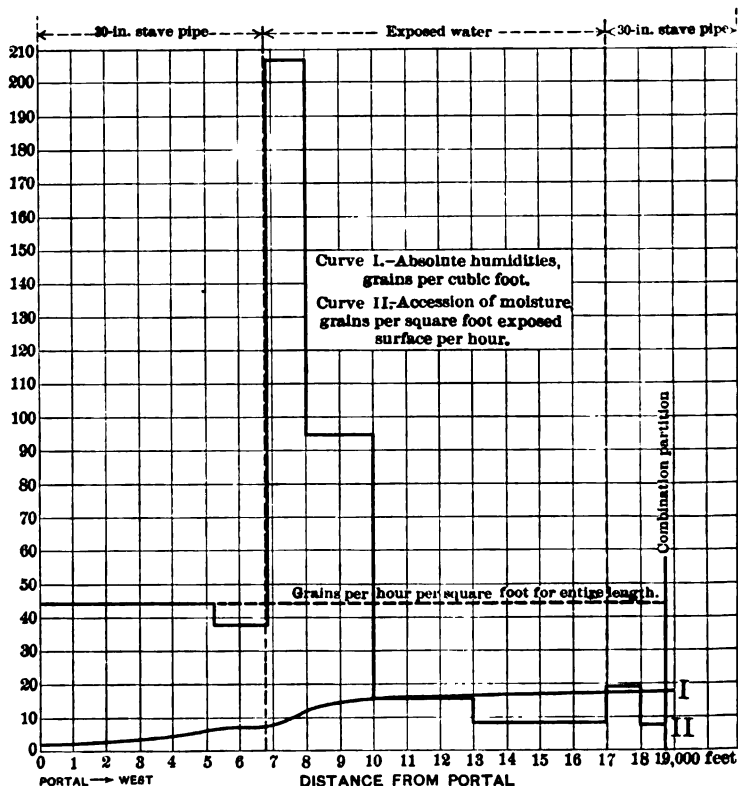


FIG. 14.—CURVES OF ABSOLUTE HUMIDITIES AND RATE OF ACCESSION OF WATER PER HOUR IN THE SUTRO TUNNEL, NOV. 22, 1908.

alone. The results have been also graphically represented in Fig. 14. The rate for the whole tunnel up to the Combination partition is 44 grains per square foot per hour. For purposes of comparison, both north and south laterals for a portion of their length were calculated. The south lateral is timbered for about one-half the distance taken. Very little water drops from the walls, and the drainage-water is carried in a stave pipe, so that

moisture comes from the walls. A rate of
und. The north lateral, on the other hand,
s and more or less water is present, although
ainage-water is carried in stave pipes. The

Three drifts have been calculated: the very
e 2,350-ft. level; the east drift of the same
n of the 2,150-ft. drift. Although the west
level is snow-shedded, the hot vapors find
with considerable freedom and give a high
r square foot per hour. The east drift of this
ely dry and practically out of the hot zone.
ver rate, 55.8 grains. The 2,150-ft. drift is
but, since the lower workings have drained
a great extent, the accession of moisture is
2 grains per hour.

fts.—Three down-cast shafts have been cal-
C. down to the 2,150-ft. level; the Yellow
level; and the Union to the 2,000-ft. level.
perature and the relative humidity at different
s are shown in Fig. 15.

It is not a very wet shaft, but considerable
rainage-water is present from the 1,750-ft. to
which accounts for the high rate of 74.17
oot per hour. The Yellow Jacket is moder-
e Union is quite dry. The rates are 51.76
pectively.

the amount of water taken up by an air-
-temperature conditions may be gained by
al amount of moisture discharged with the

The total amount in all upcasts is 519,788
vided as follows: Combination, 146,330;
elcher, 58,941; Ward, 142,377 lb. These
en calculated on the average amounts of air

III. Assuming an average temperature of
ve humidity of 50 per cent., the down-cast
underground workings 127,990 lb. of mois-
ich leavea 391,798 lb. of water per 24 hr. as
up by the air-currents. The calculated re-
ss than the actual amount.

The unit used in comparing different mine-workings is the rate of accession of water vapor per square foot of exposed surface per hour, and is calculated from the following ratio:

Volume of air in cubic feet per minute $\times$ increase in absolute humidity per cubic foot for the length under consideration $\times$ 60 min.

Square feet of exposed surface in length under consideration, or length of air-way $\times$ perimeter.

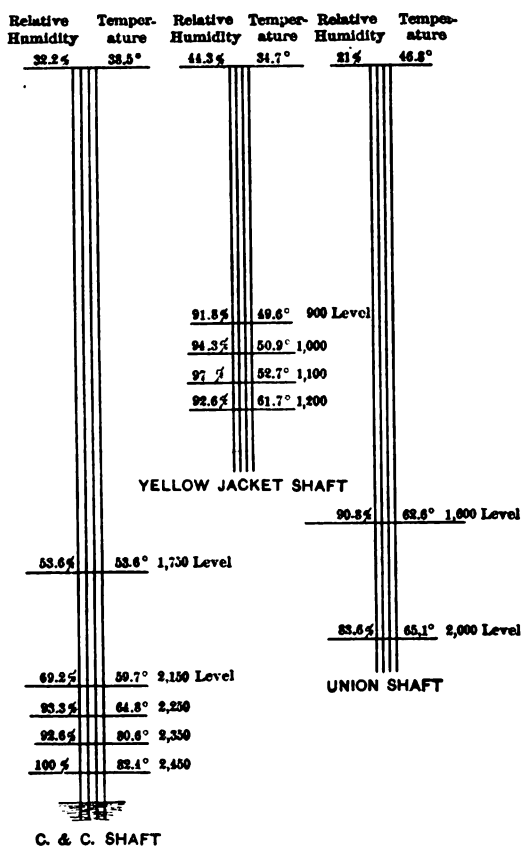


FIG. 15.—RANGE OF TEMPERATURE AND RELATIVE HUMIDITY IN DOWN-CAST SHAFTS.

VIII. CONTROL OF HUMIDITY AND HEAT.

Control of humidity and heat is a matter of considerable importance as affecting the efficiency of the miners. High temperatures and saturated air are conducive to low labor-efficiency, while, on the other hand, high temperature with low humidity does not lower efficiency to an unreasonable extent. The ex-

ous section show that if water can be kept a moderate humidity is possible, but this one. Careful boxing of drains and boarding-beneficial; the carrying of large quantities in closed conduits, such as the stave pipe, is on the whole, the mine-drift or tunnel cannot deal air-way under high-temperature conditions. Carefully the drainage-water may be carried, water-vapor from the walls and surfaces of mains as an important humidifying-agent. Moisture-tight walls for the drifts is out of the use of excessive volumes of air is impracticable. The use of air through sheet-metal conduits of iron is the only practicable way of delivering humidity to working-places where a high humidity is required, and this method is in general use upon the small size of the air-pipe as compared with the use of power-driven fans to force a current of air. The working-face of a dead end, such as a drift, is the most difficult to maintain in proper condition. As a consequence a number of measurements have been made of drifts ventilated by pipes. These measurements are given in Table XXVI.

In two cases the air is delivered practically at the temperature of the working-face or a little above it. These exceptions indicate that if a sufficient volume of air is delivered through the pipe the air can be delivered lower in temperature at the working-face, although usually the volume of air delivered with short distances the air is delivered at a temperature as the drift through which the return air flows. The quantity of air varies from 500 to 1,200 cubic feet per minute in ordinary cases, up to from 2,000 to 4,000 cubic feet per minute in cases in which an excessive temperature is to be avoided. The humidity of the discharged air depends upon the humidity of the air entering the pipe or fan and the humidity of the discharged air, and for this reason the air delivered from a current low in both temperature and humidity. The relative humidity of the discharged air ranged from 22 to 74.4 per cent., while the relative humidity at the face, beyond, ranged from 22 to 74.4 per cent.

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TABLE XXVI.—Air- and Temperature-Measurements at Drift-Ends.

Large Volumes of Air.

Place.	Temperature of Discharged Air.	Temperature of Working-Face.	Relative Humidity of Discharged Air.	Relative Humidity of Working-Place.	Distance of Working-Face from Pipe-End	Cubic Feet of Air per Minute.	Velocity of Discharge.	Diameter of Air-Pipe.
	Deg. F.	Deg. F.	Per Cent.	Per Cent.	Ft.		Ft. per Min.	In.
2,350 C. & C. shaft, west drift.....	82.4	110	.....	100	25	4,160	3,492	15
2,350 C. & C. shaft, east drift.....	89.6	96.8	40.6	50.7	40	1,986	2,050	15

Moderate Volumes of Air.

5 Gould and Curry, Sutro tunnel.....	91.0	91	31	31	12	989	1,521	11
Savage, 75 ft. above Sutro tunnel.....	92.6	92.1	37.3	51	30	894	1,856	11
Chollar, Sutro tunnel.....	104.5	.....	23.8	.....	.....	934	1,416	11
Chollar, Sutro tunnel.....	106.2	106.2	22	22	10	721	1,104	11
Hale and Norcross, cross-cut.....	108.1	107.6	21.8	32.2	15	941	1,426	11
Hale and Norcross, cross-cut.....	109.4	109.6	20.0	29.8	25	688	1,054	11
2,000 level Union, NW. cross-cut.....	99.1	98.6	38.3	43.4	20	1,271	1,042	15
2,000 level Union, south drift.....	98.6	.....	40.8	.....	30	971	796	15
2,350 C. & C. north workings.....	104.5	.....	36.5	.....	.....	544	490	15
1,200 level, Caledonia.....	86.0	87.8	41.0	74.4	25	792	1,200	11

No Active Circulation of Air.

2,000 level, Union, east cross-cut.....	100.9	.....	74.8	.....	.....	.....	.....	.....
1,100 level, Yellow Jacket, north drift to Imperial.....	89.9	.....	86	.....	.....	.....	.....	.....

the table, the west drift of the 2,350-ft. level
strates abnormal conditions. Great heat and
of moisture emanated from the rock walls,
the time been closed off by boarding, and this
current to saturation and raised the tempera-
very short distance. The east cross-cut of the
0-ft. level is a dead end, in which practically
ting, and which was also dry. The north
ft. level of the Yellow Jacket is also a dead
lating air, but with a small amount of water
drift. In neither of these drifts was the air
sture, but in both it was quite oppressive.

d use of the air-pipe as a means of delivering
currents is of course no new thing. Church
e efficiency of the system, and in particular
ng the air through metal pipes the relative
r-current is lowered and it becomes quite
ng the excessive perspiration of the miners.
nents to be noted in Comstock practice since
n's observations, about 30 years ago, are an
and a larger quantity of air, larger air-pipes,
ed metal fans instead of the slower wooden
ric motors instead of compressed-air engines,
re power.

of air-currents, resulting in the production
red in all of the upcast shafts near the sur-
aces underground where cool currents mix
air. The moisture condenses on timbers
and frequently causes the rock to swell, dis-
e. By stimulating the growth of fungi it
ses the timbers to rot. In only one place is
to remedy such a condition, and in this case
cool air is introduced into the air passing
ne. Trouble was experienced in this incline
moisture causing the "back" to swell, and
ound effective. It is evident that the intro-
r lowers the temperature of the upcast air
the efficiency of the upcast, and if too much
he opposite from the desired effect would be
g the air through the shortest and driest

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air-ways to the upcast, and the careful stopping of all leaks of cool air, would be a more effective way than that now followed.

Some observations upon the cooling-effect of large volumes of air were made. The most striking results were in the case of the hot west drift on the 2,350-ft. level of the C. & C. Before the connection was made the maximum temperature of this drift varied from 126° to 130° F., and this in spite of forcing 4,160 cu. ft. of air per minute into the face. The air in the drift was saturated and would not support a candle-flame. After making the connection and before boarding-off the walls of the drift, the temperature dropped to 110°, with a volume of air passing of 10,350 cu. ft. per min. The air-current was supersaturated. After snow-shedding, the temperature dropped to 98.6°, with 11,667 cu. ft. per min. passing and a relative humidity of 98.8 per cent. In the Hale and Norcross cross-cut, on Dec. 28, the rock-temperature measured 113° and the air-temperature 109.6°. The reduction in temperature of more than 3.4° was effected by an air-current of 688 cu. ft. per minute.

The most effective means for the control of an excessive temperature is the tight boarding of water-boxes carrying hot water, the use of boards and battens for the sides and tops of drifts, and passing large volumes of air as cool as possible.

IX. PHYSIOLOGICAL EFFECT OF WORKING IN HIGH TEMPERATURE AND HUMIDITY.

Much has been written regarding the effects upon the human system of poisonous and other gases, but very little is to be found in mining-literature concerning high temperature and humidity. Le Neve Foster says:⁵

"In still and saturated air it is hardly possible for men to do hard continuous work above 80° or 85° F., even when stripped to the waist. At higher temperatures in saturated air the amount of work possible becomes less and less, and the body temperature may rise rapidly, though men accustomed to the heat can bear it much better than others. At temperatures above about 90° by the wet bulb it is only possible to work for short periods, and it becomes difficult even to remain without working. Thus, at a temperature of 93° in still and saturated air, I found that, though I was stripped to the waist and doing practically no work, my temperature rose 5° in two hours, and was still rising rapidly when I found it necessary to come out. On the other hand, it is a well-known fact that if the air is dry much higher temperatures can be borne with ease and comfort. In collieries

⁵ *Investigation of Mine Air*, Sir C. Foster and J. S. Haldane, p. 151 (1905).

fairly dry and in motion, men can work well at a dry-bulb temperature even 100°, and in hot climates with very dry air much higher is not oppressive."

discusses the permanent effect of high heat upon man and reaches the following conclusion:

"The effect of this extreme heat on the miners' constitution is not so simple. Mine levels differ so materially in temperature, and the assigned temperature is so frequently changed from one cause and another, that it is difficult to get at present complete comparative data. That prolonged labor in a hot atmosphere will assuredly shorten life appears indisputable; but whether it is permanently or materially injured by intermittent working conditions is more questionable. The power of recuperation appears to be great unless the strain is intense and frequent, no lasting injury may result. Within the limits of permissible strain will, of course, vary with the individual's endurance. The action of all the bodily organs appears to be affected by heat, with the exception of the stomach alone."

Dane and Thomas⁷ comment on exposure to high temperatures and sudden variations of temperature as

"Commonly exposed to high temperature underground, and to cold on coming out, often with damp clothes on. Much stress is put on this fact, particularly in relation to lung diseases. Nevertheless, the important cause of lung disease, for colliers are similarly exposed. And, colliers never wash and change their clothes at the pit-head, and miners almost invariably do so, in a heated building ('dry') provided with fans. The effects of high underground temperatures on men and on the industry are of considerable interest and economic importance, and we find observations that in warm and moist air underground the temperature often rises several degrees; but we can find nothing in the literature connected with the mode of occurrence of miners' phthisis to suggest that high underground temperatures are in any way connected with its causation."

His⁸ on the immediate results of high temperatures—vapors, as absent-mindedness, dizziness, fainting, and, as graver results, insanity and death. His final conclusion is the following:

"The effects positively traceable to the heat are therefore twelve per cent. of the total. Only the heat increases the bad effects of powder fumes and naturally of the dust. See *Coal Mining and Miners, Monograph IV., U. S. Geological Survey*, p. 400

and *the Institution of Mining and Metallurgy*, vol. xiii., p. 383

and *the Comstock Mines and Their Relation to Deep Mining, Trans.*,

ral gases, and by making repairs to the shafts more frequently necessary it indirectly adds to the occasions when disasters may occur. I also confess to the belief, which is not sustained by observations upon specific casualties, that some allowance should be made for a less active mental condition, a dulling of the faculties, and a certain recklessness to which the heat sometimes goads the men. On the other hand the heat makes them more cautious except when under momentary impulses, and I have never seen American miners more careful of themselves than in these mines. On the whole the good and bad effects of the heat seem to nearly balance each other, and I think that an allowance of five per cent. for the casualties indirectly caused by the high heat would be sufficient."

The main facts brought out by these observers are that high temperatures and humidities cause, under some conditions, a notable rise in body-temperature; that all the bodily organs with the exception of the stomach are stimulated; that prolonged exposure to such conditions undoubtedly lowers vitality; that intermittent exposure produces no permanent ill-effects; that these conditions cannot be considered an important cause of lung-diseases; and, lastly, that under abnormal conditions loss of mental control and serious bodily disturbances result.

Local physicians inform me that the average life of the Comstock miner approximates 25 years, and that the miners do not show any greater susceptibility to any particular disease than the residents of the town. I am acquainted with miners who have worked more or less continuously underground for 30 years, and who are still capable of doing a good day's work. Compared with miners of other districts the Virginia City miners may be said to be just as healthful, if not more so. The result is due in a large measure to the fact that the Virginia City miner observes certain precautions, and that the mine-managements provide the necessary facilities. Miners are careful not to expose themselves to cold drafts, since they work stripped to the waist. On passing from a hot to a cold place a heavy coat is used to protect the heated body. Wet clothes are either removed before going to the surface, or trousers and coat worn over them. All miners take hot and cold showers after coming off shift. Frequent drinking, and the bathing of the hands, wrists, arms, and head in ice-water are resorted to in all hot workings, and undoubtedly serve to keep down the body-temperature, while temporarily refreshing. Frequent rests are taken in special cooling-rooms, so placed in the workings as to receive the freshest and coolest air. In exceedingly hot work-

n a hose is turned upon the miner while at

underground conditions upon the blood was a preliminary study by Prof. P. Frandsen. His results are of importance, and in consequence full in the accompanying note. His tentative conclusion is that "the conditions in the Virginia City mines do not have any detrimental effects upon the composition of the blood. In comparison of Tables XXVII. and XXIX. it is seen that the permanent effect is an increased hæmoglobin in the individual red blood-corpuscles."

Not favorable for a study of the comparative effects of working under normal temperatures and lower levels of the Comstock. The following are the results of my underground experience: temperatures, from 95° to 105° F., with moderate air-velocities, from 50 to 70 per cent. relative humidity, and air-velocities from 200 to 300 ft. per min., do not make the work particularly uncomfortable.

At temperatures, from 110° to 115°, together with the above, decreases efficiency to a considerable

extent. At temperatures, from 110° to 115°, with high humidity and weak air-currents, very greatly impairs the efficiency. At a still higher air-velocity, under the same conditions, the work is more bearable, but miners cannot long continue at one time.

At a temperature, from 95° to 105°, in a saturated atmosphere with no current, becomes very trying. Prolonged exertion is dangerous.

At a temperature, from 90° to 98°, and saturated atmosphere, with a velocity of from 400 to 500 ft. per min., with fresh air, are conditions which are very trying and inefficient. Vitiating air will impair labor to a greater extent than a high temperature.

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X. APPENDIX.

By PROF. P. FRANDSEN.*

With a view to obtaining more exact information as to the physiological effects of the atmospheric conditions in the lower levels of the Virginia City mines, some preliminary studies were made upon the blood of subject No. 1 and several miners. To determine the effect of a temporary sojourn in the mines, blood of subject No. 1 was examined at Reno, December 10, two days before going to Virginia City; December 12, after remaining 2.5 hr. in the 2,000-ft. level of the Union shaft; on December 13, after spending 4.5 hr. in the Sutro tunnel and south lateral; and on December 14, at Reno. The temperatures in the workings visited ranged from 100° to 109°, with humidities of from 60 to 100 per cent. During both trips the subject and myself perspired profusely while underground, but felt no ill-effects other than a slight dizziness and a natural fatigue. The results of the examinations are given in Table XXVII.

TABLE XXVII.—*Subject No. 1.*

Date.	Place.	Red Corpuscles per c.c.	Leucocytes (white corp.) per c.c.	Hemoglobin.	Hemoglobin Index.
				Per Cent.	
Dec. 10...	Reno.....	5,160,000	7,111	95	92
Dec. 12...	Va. City, underground	4,820,000	12,333	...	...
Dec. 13...	Va. City, underground	6,496,000	12,277	100	77
Dec. 14...	Reno.....	6,220,000	9,888	95	76

The difference in red-counts on December 10 and December 12 may be ignored as too slight to have any significance. On December 13, however, after the longer sojourn underground, there was an appreciable increase of red corpuscles, which is still to be noted on the following day. On both occasions there was a considerable leucocytosis, due mainly, as Table XXVIII. shows, to an increase in the number of neutrophils.

Tables XXIX. and XXX. give the results of examinations of five miners who have been engaged in mining for 10 years or more, and for a year or more have been at work under the conditions described in this paper as characteristic of the deeper

* Professor of Biology, University of Nevada.

—*Differential Count of Leucocytes (White Blood-Corpuscles).*

	Percentage of Varieties.				
	Lymphocytes.	Mononuclears.	Neutrophils.	Eosinophiles.	Mast.
	41.5	2.5	55.5	0.4	0.1
	32.0	2.0	65.0	0.9	0.1
	32.8	2.4	64.1	0.5	0.2
	44.6	3.7	49.0	2.5	0.2

subjects were in a fair state of health, and men-
 ue, well nourished, and moderate users of
 nor. The examinations were made as soon as
 the surface at the close of their day's shift, and,
 e of subject No. 2, before the shower which all
 of the day's work.

—*Summary of Examinations of Blood of Miners.*

Red Corpuscles per c.c.	Leucocytes per c.c.	Hæmoglobin.	Hæmoglobin Index.	Pulse.	Temperature.
		Per Cent.			
4,236,000	6,000	115	1.35	80	97.4
5,386,000	7,814	120	1.11	76	97.2
4,460,000	10,777	120	1.34	70	98.2
5,178,000	7,055	111	1.07	80	98.2
5,422,000	12,277	114.5	1.05	61	99.1

—*Differential Count of Leucocytes of the Blood of Miners.*

	Percentage of Varieties.				
	Lymphocytes.	Mononuclears.	Neutrophils.	Eosinophiles.	Mast.
	36.8	5.8	56.6	0.4	0.4
	52.4	3.2	48.5	0.5	0.4
	40.7	3.5	54.0	1.0	0.8
	53.3	2.3	43.1	0.8	0.5
	34.3	3.7	59.1	2.8	0.7

iking feature revealed by Table XXIX. is the
 hæmoglobin index of the miners' blood. The



as the published accounts of other observers expect in these altitudes. In comparison with the number of red corpuscles obtained in the miners would not seem to be very far from the initial leucocyte-counts were made on the blood, as given in Table XXXII.

Differential Count of Leucocytes in Relation to Altitude.

Percentage of Varieties.				
Lymphocytes.	Mononuclears.	Neutrophils.	Eosinophiles.	Mast.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
41.5	2.5	55.5	0.4	0.1
33.4	4.5	57.6	3.5	1.0
32.2	5.4	60.4	1.7	0.3
44.4	5.2	49.2	1.0	0.2
42.0	5.5	50.0	2.1	0.4

It to be noted is the relatively high percentage

studies are too few to warrant an extended dis-
statement of any very definite conclusions, they
indicating that the atmospheric conditions in
of the Virginia City mines do not have any
imental effects upon the composition of the
comparison of Tables XXIX. and XXXI., it
main permanent effect is an increased hæmo-
f the individual red corpuscles.

ACKNOWLEDGMENTS.

the foregoing data I received many courtesies
of the Ophir mine, the Sutro Tunnel Co., the
ining Co., the Caledonia, and Overman Mining
cially to acknowledge the assistance of Dwight
Virginia Mining School; T. McCormick, super-
Ophir mine; T. Sullivan, of the Ophir mine;
man of the Sutro tunnel; and Leon M. Hall,
aft Pumping Association. To Professor Frand-
tribution, I am particularly grateful.

indefinitely suspended. To the settled, coagulated portion some writers have given the term *gel*, and to the suspended portion the term *sol*. The physical properties which distinguish the fine sands are, the angular character of the grains and the comparatively rapid settling in water. With most quartzose ores the sand grains are composed of silica, although constituents of the ore, such as silicates or oxides, also characterize the sand portion of the slime. The coagulated colloid consists of aggregates of rounded grains together with individual grains, settles much less rapidly, possesses the property of flocculation and deflocculation, has the property of absorbing certain dyes, and a distinctive chemical composition. Clays and hydrated silica are the two colloids most likely to occur in quartzose ore. The former is a common constituent of many ores, the latter is perhaps seldom present. For practical purposes clay, or hydrated aluminum silicate, may be considered to be the chief colloidal constituent, and, mixed with fine sand, to constitute the coagulated portion of a slime. Inasmuch as the ordinary mill-slime is quite well coagulated by the liberal use of lime, the metallurgist has to deal only with mixtures of fine sands and coagulated colloid.

The distinctive properties of a slime depend upon the relative proportions of fine sand and colloid. Assuming all colloid and no fine sand, we would have a material which could not be leached, and which would filter very slowly and under certain conditions not at all; assuming all fine sand and no colloid, we would have a leachable material. In a moist condition a slime may be likened to a clay; with a large proportion of sand a "short clay" or a clay of moderate plasticity would be the result; with a small proportion of sand a "fat" clay or a clay with a high degree of plasticity would result. With sufficient moisture a slime partakes of the character of a viscous fluid, and in this very fine sand will be almost indefinitely suspended, and little or no separation of fine sand from colloid will result. This latter statement is true of sand finer than a 150-mesh screen. With coarser sand, the coarse sand particles tend to settle out quite rapidly. By increasing the proportion of water successive crops of finer and finer sands can be settled out until a point is reached where the particles of coagulated colloid and the finest sands settle at the same rate. Beyond

separation of sand from colloid is possible. The mechanical separation of sand from colloid is possible, it is necessary to use a definition with some limitation as to the size of the maximum particle.

Successive screen-sizes have been used; first a 100-mesh screen, then a 150-mesh screen, and, finally, a 200-mesh screen, and this is the accepted present practice in the treatment of material in a pulp finer than a 200-mesh screen, and as slime. The definition, that a slime is a fine material from a mill-pulp, is still in use.

A more comprehensive definition than the foregoing is: a mixture of sands finer than 150- or 200-mesh, with an amorphous clay-like material, consisting of finely divided aluminum silicate.

The method of slime-treatment is to agitate the slime in water for a sufficient time to dissolve the solution, then to filter off the surplus solution and disperse the residue with water, or to thicken the slime by concentration, and then to filter and displace the residue with water.

The appliances in use for filtration are grouped

into three classes, or filters in which a vacuum is used to accelerate filtra-

tion, (a) in which the slime-cake and practically continuous in their action. (b) in which the slime-cake and practically continuous in their action. (c) in which the slime-cake and practically continuous in their action.

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¹ *Trans.*, xli, 349 to 356 (1911).

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Slime-Filtration.

BY GEORGE J. YOUNG,* RENO, NEV.

(San Francisco Meeting, October, 1911.)

Slimes handled in the treatment of gold- and silver-ore have been discussed in technical literature to a considerable extent. The subject of slime-filtration from the practical point of view has also received much comment, and much of the literature of the subject are descriptions of filtration installations. Articles of this nature are intended to inform and assist materially in the design of new plants and the improvement of old plants. The subject of the slime-filtration has been touched upon to only a small extent. The underlying principles are worthy of more study and experimentation than they have received. The purpose of this paper is to present the results of experimental work as will serve to make clear many of the principles which control the filtra-

Nature of Slime.

There has been much written concerning an accurate definition of "slime," but no comprehensive definition seems to be in vogue. The reason for this is clear. A slime is not a single substance, but at least three different substances, each, when separated, having distinctly different physical and to a certain extent different chemical properties. These substances are extremely fine, colloidal material which may be and generally is in a liquid condition, and a colloidal material which is in a solid condition. Suspending a slime in a relatively clear water by shaking and allowing sedimentation results in the fine sand settling out with comparatively little delay, followed by the coagulated material, which settles more slowly and finally a certain portion remains

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indefinitely suspended. To the settled, coagulated portion some writers have given the term *gel*, and to the suspended portion the term *sol*. The physical properties which distinguish the fine sands are, the angular character of the grains and the comparatively rapid settling in water. With most quartzose ores the sand grains are composed of silica, although constituents of the ore, such as silicates or oxides, also characterize the sand portion of the slime. The coagulated colloid consists of aggregates of rounded grains together with individual grains, settles much less rapidly, possesses the property of flocculation and deflocculation, has the property of absorbing certain dyes, and a distinctive chemical composition. Clays and hydrated silica are the two colloids most likely to occur in quartzose ore. The former is a common constituent of many ores, the latter is perhaps seldom present. For practical purposes clay, or hydrated aluminum silicate, may be considered to be the chief colloidal constituent, and, mixed with fine sand, to constitute the coagulated portion of a slime. Inasmuch as the ordinary mill-slime is quite well coagulated by the liberal use of lime, the metallurgist has to deal only with mixtures of fine sands and coagulated colloid.

The distinctive properties of a slime depend upon the relative proportions of fine sand and colloid. Assuming all colloid and no fine sand, we would have a material which could not be leached, and which would filter very slowly and under certain conditions not at all; assuming all fine sand and no colloid, we would have a leachable material. In a moist condition a slime may be likened to a clay; with a large proportion of sand a "short clay" or a clay of moderate plasticity would be the result; with a small proportion of sand a "fat" clay or a clay with a high degree of plasticity would result. With sufficient moisture a slime partakes of the character of a viscous fluid, and in this very fine sand will be almost indefinitely suspended, and little or no separation of fine sand from colloid will result. This latter statement is true of sand finer than a 150-mesh screen. With coarser sand, the coarse sand particles tend to settle out quite rapidly. By increasing the proportion of water successive crops of finer and finer sands can be settled out until a point is reached where the particles of coagulated colloid and the finest sands settle at the same rate. Beyond

further separation of sand from colloid is possible. In the mechanical separation of sand from colloid being possible, it is necessary to use a definition embody some limitation as to the size of the maximum grain. Successive screen-sizes have been used; 20-mesh screen, then a 150-mesh screen, and, finally, a 200-mesh screen; and this is the accepted present practice in the United States. All material in a pulp finer than a 200-mesh is considered as slime. The definition, that a slime is the fine portion of a mill-pulp, is still in use.

A more comprehensive definition than the foregoing is: a mixture of sands finer than 150- or 200-mesh, with an amorphous clay-like material, consisting of hydrated aluminum silicate.

The usual method of slime-treatment is to agitate the slime in a solution for a sufficient time to dissolve the slime, either to filter off the surplus solution and discard the remainder with water, or to thicken the slime by filtration and decantation, and then to filter and displace the solution by water.

Mechanical appliances in use for filtration are grouped

into three classes: vacuum-filters, or filters in which a vacuum is used to accelerate filtration.

1. Vacuum-filters, or filters in which a vacuum is used to accelerate filtration, using a thin slime-cake and practically continuous in their action. (Moore and Ridgway filters.)

2. Vacuum-filters, or filters in which a vacuum is used to accelerate filtration, using a thick slime-cake and intermittent in their action. (Moore and Ridgway filters.)

3. Pressure-filters, or filters in which hydrostatic head, compressed air or steam pumps are used in order to secure greater pressures than are possible with a vacuum-pump.

4. Pressure-filters, or filters in which hydrostatic head, compressed air or steam pumps are used in order to secure greater pressures than are possible with a vacuum-pump.

5. Filter-presses.

6. Filter-presses (Merrill filter-press).

7. Filter-baskets or cylinders; filters in which the filtering-basket is in a cylinder. (Burt, Kelley, and Sweetland filter-presses.)

8. Centrifugal filters, or filters in which centrifugal force is used to separate solution from slime.

9. Centrifugal filters, or filters in which centrifugal force is used to separate solution from slime.

10. Centrifugal filters, or filters in which centrifugal force is used to separate solution from slime. In Sections I. and II., with the exception of the centrifugal filters, employ vertical filtering-surfaces. The Oliver¹ makes

¹ *Trans.*, xli, 349 to 356 (1911).

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use of a revolving cylindrical surface as a filtering-surface. Centrifugal filters are in process of development, and have not as yet secured any foothold in gold- and silver-metallurgy. It is not improbable, however, that some comparatively simple filter based on the use of centrifugal force will be perfected, and will successfully compete with the other forms. At present the suction-filters are in greatest use. Of the pressure-filters, the ordinary filter-presses have gone out of use, except as clarifying-presses, and filters of groups *D* and *E* only are in use.

The development of slime-filtration is of interest. Filter-presses and filtering-beds in vats were first used. The filtering-beds were soon discarded and the filter-press systematically developed. The size of the press was increased, mechanical devices to facilitate discharge and decrease the proportion of labor required were invented and introduced; but in spite of all this the cost of treatment in filter-presses remained high. In western America the filter-press never received much recognition, but in Australia filter-pressing was extensively introduced, and slime was successfully handled by this method. It remained for an American, Charles A. Merrill, to complete the last improvement in the filter-press. By the introduction of the sluicing-system the slime-cakes could be washed out of the filter-cells and the press operated without opening or separating the filter-plates for each charge. This improvement reduced the labor and cost and increased the effectiveness of the filter-press. The Merrill press represents the culminating point in the filter-press line of development in slime-filtration.

The Moore filter was the first suction-filter in the field, and, while it did not score any very decided success in the first installations, it did attract the attention of metallurgists to the idea involved. While the Moore Filter Co. was perfecting the mechanical features of its filter, the Butters filter was introduced, and so many of the difficulties of the Moore filter were overcome in the Butters, that this latter filter received widespread recognition and was introduced into many milling-plants. The Moore filter introduced the idea of the canvas-covered filtering-cell immersed in the slime-pulp and utilizing suction to draw the solution through the walls of the cell and to build up a cake. The necessary transfers are made by lift-



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ing-basket out of the pulp. The Butters filter is the idea of a stationary filtering-cell, and effected by pumping the slime-pulp and wash-water from which the filtering-cells were immersed. The relation of the two systems have been sufficiently discussed in the literature. Both the Moore and the Butters reached a point where little or no further improvement was possible. Like the Merrill, either one of these filters satisfactorily meet the requirements of slime-

filtration of the ideas involved in the filter-press. The filter-press is seen in group *E*, or the filtering-cells of the Kelley, the Burt, and the Sweetland may be substituted for a Butters filter installed in a pressure-tank.

The use of a continuously-acting filter has resulted in many different types being developed, of which the Ridgway and the Merrill are the best known. Both of these filters utilize a very thin slime-cake. Both operate very successfully compared with the thick-cake machines have advantages, briefly stated as: simplicity of design; probability of capitalization-charges for equal capacities; lower cost; and less attention required in the operation.

In the exception of the Oliver filter, the general method of operation of both suction- and pressure-filters is the same. Pulp is delivered to the filter in the proportion of one part of pulp to from three to one of solution. The pulp enters the cells of the pressure-filters and a cake formed on the canvas walls of the cells, the surplus pulp, if any, is removed and wash-water forced in until the contained solution is displaced. The cake is then forced off from the canvas either by water or air or a combination of both, and is carried out. In the vacuum-filter the filtering-cells are submerged in the pulp, a vacuum is formed, and a cake built up; the pulp is then withdrawn either by lifting the filtering-cells or by withdrawing the pulp by pumps, and the cakes are removed in water for washing. In the Moore filter the cakes are discharged by forcing them off from the cell by water pressure, dropping into a hopper for sluicing away; in the Sweetland the cake is forced off in the same way, but while still submerged in the wash-solution. The wash-solution is then

withdrawn, either by decanting or pumping, and the slime-cake and surplus wash sluiced out. The Oliver filter performs the operations of cake-formation, washing, and discharge in continuous sequence. Three steps may be designated as common to all these filters: cake-formation, washing, and discharge. The cycle of operations of the more common forms of filters is shown in Fig. 1. Typical examples have been taken in each case.

The conditions under which slime-cakes are formed and washed are the critical points to be considered; the discharge and sluicing away of the cake is a comparatively simple mat-

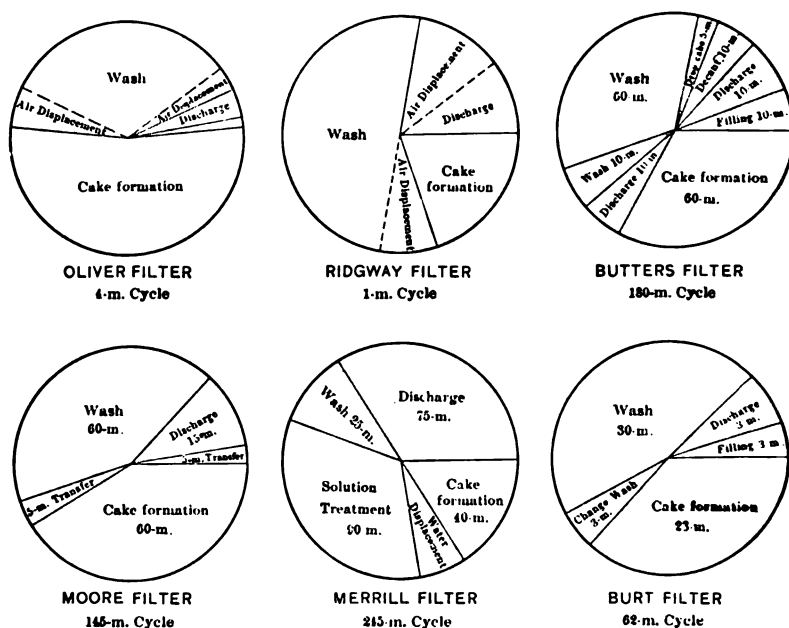


FIG. 1.—CYCLE OF OPERATION OF VARIOUS FILTERS.

ter and requires no special comment. My experimental work was largely confined to suction-filtration, and pressure-filtration was only briefly studied. The method of carrying out the experiments may be summarized as follows: After trying out several different sizes and types of filter-cells a test-filter of 0.5 sq. ft. filtering-surface was decided upon, shown in Fig. 2. A ribbed wooden support with $\frac{1}{8}$ -in. grooves and $\frac{1}{8}$ -in. ribs was used to support the canvas surface. Brass side-strips and a

bottom-strip were used to protect the cake and measuring. A type slime was obtained by classify- from a Tonopah quartzose ore which had been stamp-battery. The slime was settled by the use then by repeated settlement all the coarse and as fine sand as possible were settled out and removed.

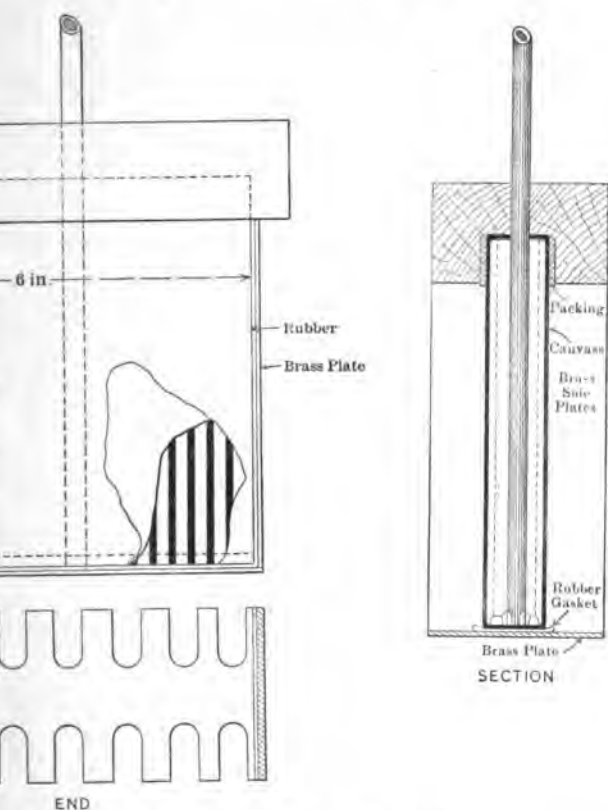


FIG. 2.—FILTER USED IN EXPERIMENTAL WORK.

slime remaining was settled to a thickness giving a
3. The screen-analysis of this slime approximated:

	Per Cent.
Fine,	0.1
minus 100,	1.3
minus 150,	1.20
0, and less than 2 min. settling,	20.0
from 2 to 4 min.,	8.5
from 4 to 8 min.,	11.6
coarser,	54.3

Of this slime-pulp, 97.4 per cent. passed a 200-mesh screen. Fine sand passing a 100-mesh screen was used in securing the necessary mixtures. The filtrate was measured in a Woulff bottle, to which was attached a vacuum-gauge. The vacuum was obtained by a small single-acting pump exhausting from a 10-gal. vacuum-tank. A short length of hose connected the Woulff bottle with the tank. The slime-mixtures were made up in buckets and heated to the temperatures as required. Variations in pressure, temperature, and slime were the main points studied.

Filtering-Rate.

The rapidity with which a cake may be formed depends upon the filtering-rate of the slime, the thickness of the cake, the temperature and density of the pulp, and the intensity of the vacuum. The filtering-rate of a slime, which is numerically defined in this paper as the number of pounds of water drawn through 100 sq. ft. of filtering-surface per minute, depends, for a cake of given thickness, upon the character of the slime, the density of the slime-cake, the suction-pressure, the temperature, and, to a moderate extent, upon the character of the filtering-surface and its support. These factors are so interrelated that it is impossible to conduct any series of experiments which would exactly show the effect of varying them. At best the results are approximations.

Fig. 3 shows the variation of the filtering-rate with variable thickness of slime-cake both while building up and in clear water. The curves represent the averages of a number of tests in which temperature and pressure were practically the same for all. A No. 10 canvas was used. In carrying out the experiment the filter was immersed in the pulp for 5 or 10 min. and a cake built up. This cake was then quickly removed, its thickness measured, and the filter immersed in clear water. After determining the filtering-rate, the filter was replaced in the pulp and an additional thickness built up. The filtering-rate during building up was determined by calculation from the amount of water passing while building to a given thickness. The difference between the two curves is comparatively slight and indicates that the filtering-rate during building up a cake is greater in the pulp than in clear water for thin cakes, while for the thicker cakes the reverse is true.

the effect of variation of pressure upon the fil-
cakes of varying thickness. Three pressures
.35, 17, and 21.5 in. of mercury. The last
at the maximum obtainable in Nevada practice.
ect of increase of pressure is to increase the fil-
his is more marked with the thin cakes, while
cakes all three curves tend to run together.
es the effect of an increase of pressure is to in-
ity of the cake and thus reduce its permeability.
pressures this effect is more marked, and indi-

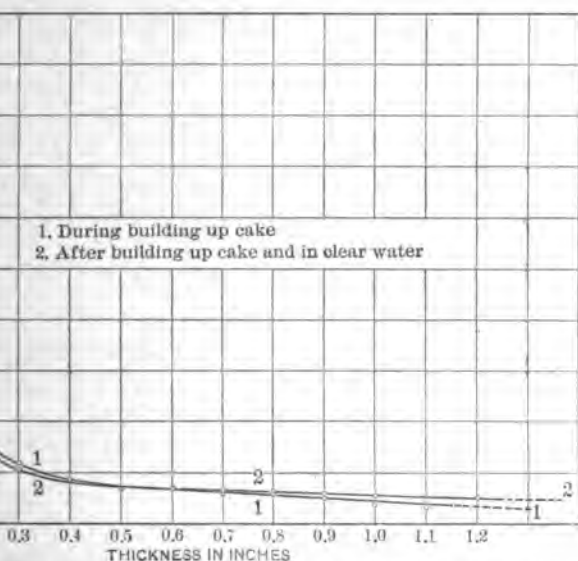


FIGURE 1. FILTERING-RATES FOR SLIME-CAKES, No. 10 CANVAS.

nt would soon be reached where the increased
result in decreased filtering-rate. This is par-
slime containing a small proportion of sand, and
with slimes containing a large proportion of sand.
his paper, Pressure Filtration,² shows for pres-
5 lb. per sq. in. a progressive increase in the
r slime-cakes varying from 0.5 to 1.75 in. The
e Sweetland experiments was obtained from the
olidated mill. Unfortunately, neither a physical
slime nor the density of the slime-cakes formed

Scientific Press, vol. xcix., No. 26, p. 853 (Dec. 25, 1909).

Of this slime-pulp, 97.4 per cent. passed a 200-mesh screen. Fine sand passing a 100-mesh screen was used in securing the necessary mixtures. The filtrate was measured in a Woulff bottle, to which was attached a vacuum-gauge. The vacuum was obtained by a small single-acting pump exhausting from a 10-gal. vacuum-tank. A short length of hose connected the Woulff bottle with the tank. The slime-mixtures were made up in buckets and heated to the temperatures as required. Variations in pressure, temperature, and slime were the main points studied.

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systems, experiments should be made with different vacuum, for it may be found that a vacuum lower than the maximum obtainable with the available apparatus will give a higher filtration-rate, and thus decrease the time for cleaning up and washing.

Fig. 1 shows the comparative filtering-rates of five slimes. The same filter, temperatures, and pressures were used in all cases. No. 10 canvas was used on the filter. The slimes were: (A) a type slime (a very plastic fire-clay) containing 6.5 per cent. of sand which settled out in 1 min.; the results on the type slime; a slime from a Virginia City slings-pond; the type slime containing 37 per

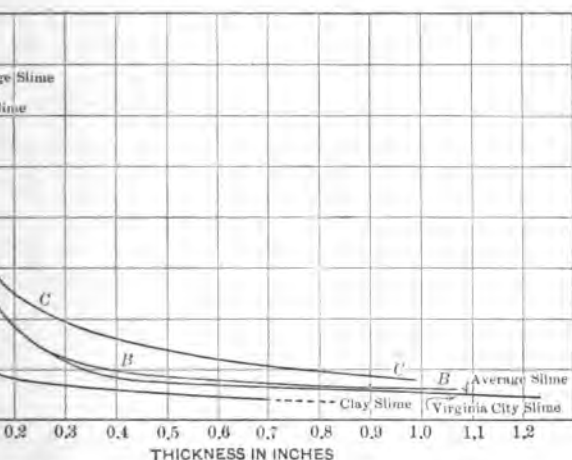


Fig. 1. FILTERING-RATES OF FIVE SLIMES, No. 10 CANVAS.

cent. of sand (determined on the basis of 1 min. settlement) and a type slime with 52 per cent. of fine sand (determined on the basis of 1 min. settlement). The type slime on which the 6.5 per cent. of fine sand was based gave 6.5 per cent. of fine sand. The results respectively represent the 37 and the 52 per cent. of fine sand in the slimes.

The filtering-rate curves for the type slime and the Virginia City slime are coincident. The increase in the proportion of fine sand from 6.5 to 37 per cent. makes but very little difference in the filtration-rate. A further increase to 52 per cent. of fine sand makes a marked increase in the filtering-rate (curve C). While the type slime has a greater proportion of fine sand than either

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is given in the paper. The slime-pulp of the Goldfield Consolidated mill is distinctly of a sandy nature and would be expected to give results of this kind, whereas a very clayey pulp would give results of an opposite character. Experiments with a slime similar to the type slime, and with pressures ranging from 10 to 30 lb. per sq. in., showed an increase in filtering-rate from 11 to 16 lb. of water per 100 sq. ft. per min. for a cake of 0.25 in. thick; for a 0.5-in. cake an increase in pressure from 20 to 30 lb. decreased the filtering-rate from 10 to 7 lb.; for a 0.75-in. cake an increase in the filtering-pressure from 20 to 30 lb. made no difference in a filtering-rate of 6 lb. R. Gilman Brown, in his paper, *Cyanide Practice with the Moore Filter*,³ in discussing the treatment of a very clayey

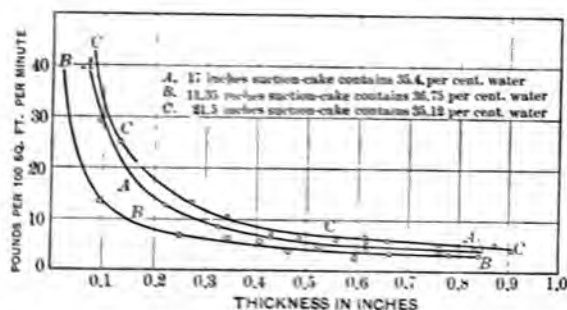


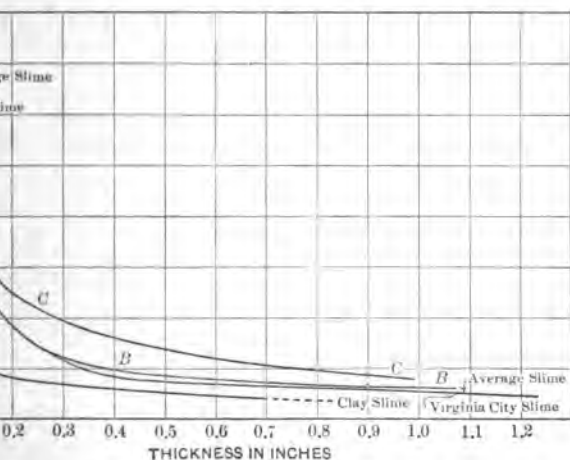
FIG. 4.—EFFECT OF VARIATION OF PRESSURE UPON FILTERING-RATES, No. 10 CANVAS.

slime at Bodie, says: "Filter-pressing was tried and abandoned, because an eighth of an inch of pure slime would make the cloths impervious, even under 120-lb. pressure; and even if the slime was mixed with fine sand, the filtering was so slow that the sand settled out in the chambers, with the same result." The practical conclusion that may be drawn from a study of the effects of pressure in filtration is that, with material of a permeable nature such as a sandy slime, increased pressures over those obtainable by means of vacuum-pumps are advantageous, while with material in which only a moderate to a small amount of sand is present and the permeability low, the use of higher pressures offers no advantages over those obtainable by vacuum-pumps. In the use of both the Moore and

³ *Mining and Scientific Press*, vol. xciii, No. 9, p. 261 (Sept. 1, 1906).

systems, experiments should be made with different vacuum, for it may be found that a vacuum lower than the maximum obtainable with the available apparatus will give a higher filtration-rate, and thus decrease the time for setting up and washing.

Fig. 1 shows the comparative filtering-rates of five slimes. The same filter, temperatures, and pressures were used in all cases. No. 10 canvas was used on the filter. The slimes were: (A) a clay slime (a very plastic fire-clay) containing 52 per cent. of sand which settled out in 1 min.; the results on the type slime; a slime from a Virginia City mill-pond; the type slime containing 37 per



FILTERING-RATES OF FIVE SLIMES, No. 10 CANVAS.

cent. of sand (determined on the basis of 1 min. settlement) of the type slime with 52 per cent. of fine sand (determined on the basis of 1 min. settlement). The type slime on the basis of 1 min. settlement gave 6.5 per cent. of fine sand. The curves A and B respectively represent the 37 and the 52 per cent. of fine sand.

The filtering-rate curves for the type slime and the Virginia City slime are coincident. The increase in the proportion of fine sand from 6.5 to 37 per cent. makes but very little difference in the filtering-rate. A further increase to 52 per cent. makes a marked increase in the filtering-rate (curve C). While the Virginia City slime has a greater proportion of fine sand than either

the type or *B*, the filtering-rate curve is much lower. The conclusions which may be drawn from these experiments are: slimes from similar ores subjected to the same metallurgical treatment give similar filtering-rate curves; a moderate variation in the proportion of fine sand gives filtering-rates differing

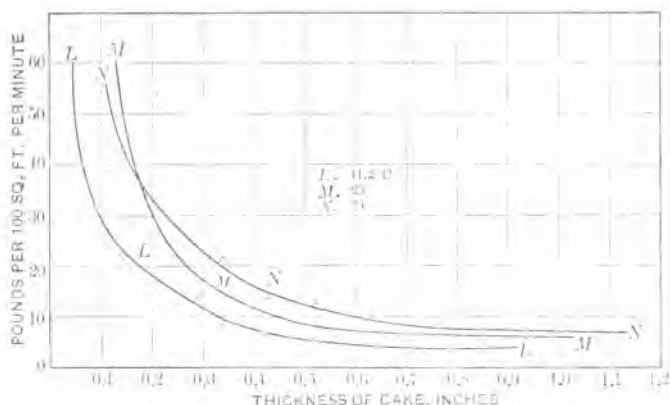


FIG. 6.—EFFECT OF TEMPERATURE UPON FILTERING-RATES OF SLIME-CAKES, No. 12 DUCK.

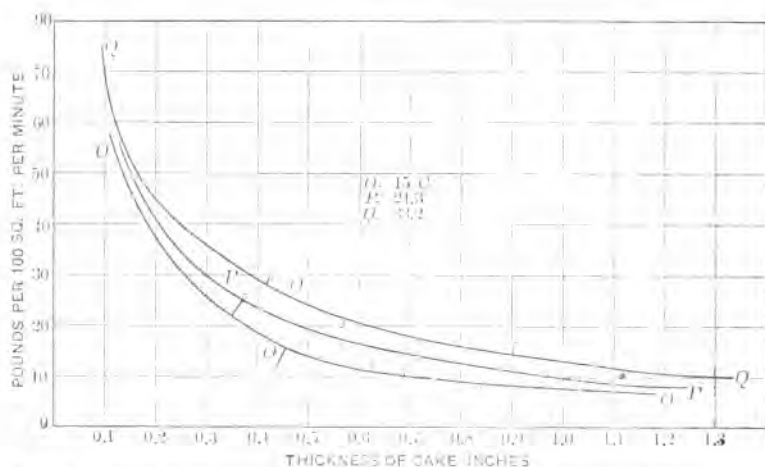
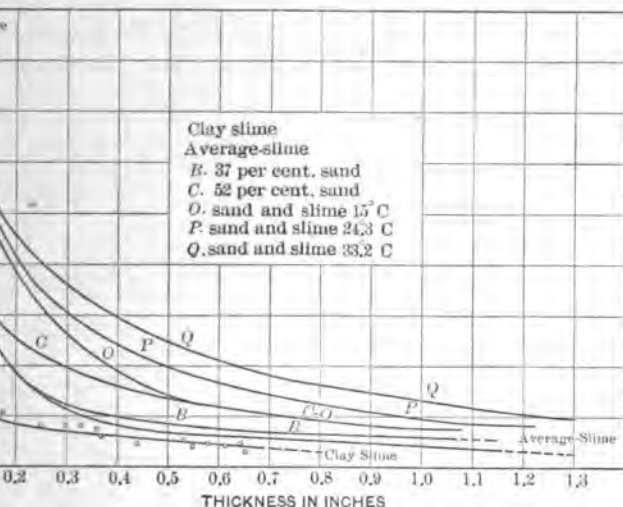


FIG. 7.—EFFECT OF TEMPERATURE UPON FILTERING-RATES OF SADD- AND SLIME-CAKES, No. 12 DUCK.

only to a small degree, while a considerable increase in the proportion of fine sand increases the filtering-rate; the proportion of colloidal matter, or, in this case, clay base, has a marked influence upon the filtering-rate; much more, relatively, than

fine sands in increasing the filtering-rates. The clay is the dominating factor in filtering-rates, and is indicated by the curves approaching a common thickness of the cake is increased.

shows the effect of temperature upon the filtering-rate of slime. A No. 12 canvas was used on the filter for experiments. For thin cakes the increase in filtering-rate is marked than for the thicker cakes. The same temperature-curves to run together for the thicker cakes are indicated.



8.—COMPARISON OF FILTERING-RATES, No. 12 CANVAS.

shows the effect of temperature upon a slime containing 37 per cent. of fine sand and the type slime. The marked increase in filtering-rate, with moderately elevated temperature, is noticeable as to indicate a condition of considerable importance. By increasing the temperature of the filter capacity could be readily obtained with a given thickness of cake. Fig. 8 compares the filtration-rates of the clay slime, the sand and the several sand-slime cakes. Fig. 9 compares the filtering-rates for fine-sand beds 3 in. thick under varying

Filtering-Surfaces.

the suction-filters employ No. 10 canvas duck for the filtering-surface. The Oliver filter makes use of a No. 12

and the Merrill filter-press of a No. 6 duck over a light twill. In the Butters and the Moore filters three methods of support are in common use. The original Butters unit consisted of canvas stitched at close intervals over a center sheet of cocoa matting, which gives a very porous gathering-space for the solutions and also sufficient support to the canvas. The objections to this construction are the cost, and the clogging of the matting. With the exception of the Goldfield Consolidated mill, all the mills in the Tonopah and Goldfield districts employ the "slat method" of support, which consists of sewing the canvas walls of the cell into narrow pockets from 1.5 to 2 in. wide, and into each of these slipping a grooved lath. The arrangement is low in first-cost and very satisfactory. The Moore system employs

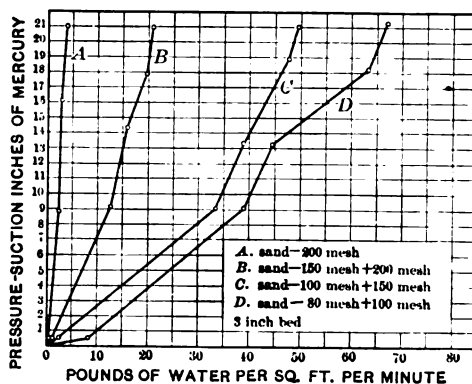


FIG. 9.—FILTERING-RATES FOR FINE-SAND BEDS.

wooden strips slipped into narrow pockets in the canvas. The Moore system also makes use of wire netting between the canvas walls, the canvas being stitched at frequent intervals through the netting. In the Oliver filter, wire netting over a grooved board and covered with 8-oz. burlap supports the canvas. The canvas is held against this base by wire wrapped around the canvas at 0.5-in. intervals. In both the Butters and the Moore filters wooden dividing-strips are used to space the filtering-surface into strips 1 ft. wide. Grooved iron plates are used in the filter-presses and in the Merrill press.

Durability and permeability are the necessary requirements of a filtering-cloth. Canvas duck, army weave, No. 10, answers both of these requirements for suction-filters. For pressure-

Canvas is too light, and No. 6 gives sufficient durability without interfering with the filtration too much. On wire wrapping, the Oliver filter can employ a lighter cloth. The relative permeability of different weights of cloth is a difficult matter to determine experimentally. It is determined by the weave of the cloth and the character of the support. In general, the lighter the weight of the cloth, the more permeable it is. Duck may be obtained in several varieties: army duck, in which the threads of warp and woof are twisted; double-fill, in which the warp thread is twisted and the woof threads are not twisted; single-fill, in which the warp threads are not twisted and the woof threads are twisted. Of

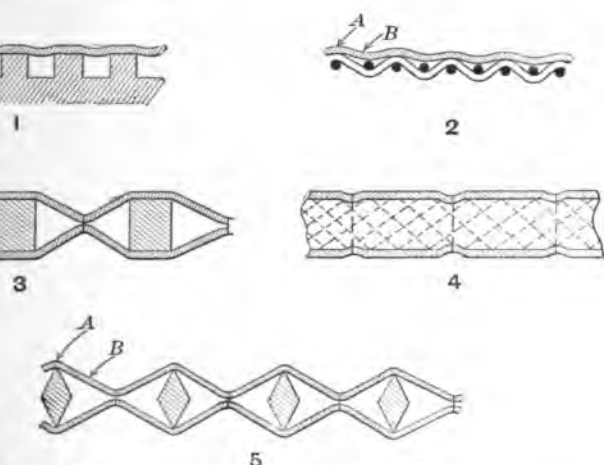


FIG. 10.—METHODS OF SUPPORTING FILTER-CLOTH.

Of these, the army duck is the least permeable, while the others are too open and porous to be of much use in filtration.

Figure 10 illustrates several methods of supporting the filtering cloth. In method 1, the fibers of the cloth are distended and made more open at B, while at A the fibers are flattened against one another, with the result of reducing the permeability of the cloth over the ridges. The proportion of ridge to groove determines the decrease in permeability due to the support. No. 2 shows the wire net support, and with this the rounded wires reduce the permeability to a less extent than the flat wooden ridges. In No.

3 the narrow wooden strips have less effect than the close ridges of No. 1, while between the strips the cloth is stretched and is more open. With No. 4 the permeability of the cloth is not generally effected, for the fibers may press into the soft cocoa matting. In No. 5 the diamond-shaped strips give the maximum proportion of distended canvas, and leave the fibers free from any flattening due to the pressure.

Fig. 11 shows the effect upon the filtering-rate of the type slime for three filters. Curve *L* is for No. 12 duck on a grooved wooden support similar to No. 1, Fig. 9; 41 per cent. of the cloth was supported and 59 per cent. unsupported. Curve *S* is for No. 12 duck supported on diamond-shaped

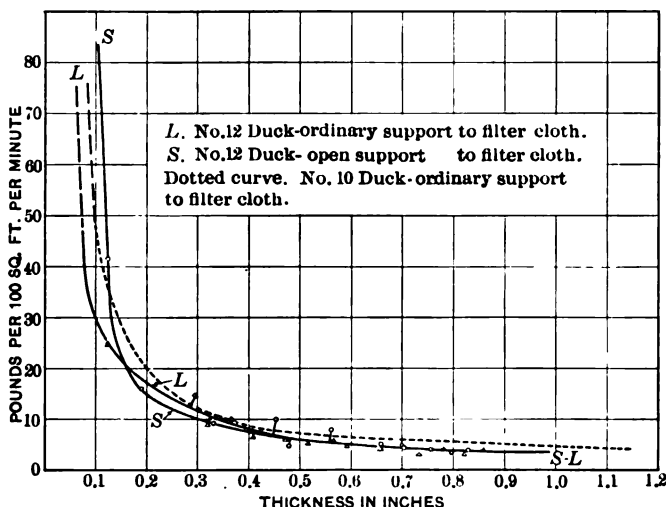


FIG. 11.—FILTERING-RATE OF TYPE SLIME FOR THREE TYPES OF FILTERS.

strips; 21 per cent. of the cloth was supported, 78 per cent. unsupported. The dotted curve is the average curve for the test-filter. A No. 10 duck was used and the same proportion of support given the cloth as for curve *L*. The heavier-weight duck on the grooved support gives a higher filtering-rate than the light weight on either the grooved or the more open support. The open support gives a higher filtering-rate for the thinner slime-cakes and lower rates for the thicker cakes. This anomalous result is explained by the fact that the more permeable the filter the more active becomes the filtering-surface for a given pressure and the more compactly the cake

next the canvas, 33.3 per cent. of water. The respective specific gravities are 1.575, 1.605, and 1.715. The average water-content is 38.1 per cent., and the average specific gravity, 1.632. *F* and *G* are from two slime-cakes in which the respective proportions of sand were 37 and 52 per cent. The composition of sections of these cakes is given in Table I.

TABLE I.—Composition of Slime-Cake.

CAKE F.				
	Surface 1 to 0.75 In.	0.75 to 0.5 In.	0.5 to 0.25 In.	Next Canvas 0.25 to 0.0 In.
Specific gravity of cake, .	1.755	1.805	1.822	1.835
Per cent. of water,	32.7	29.83	28.41	27.9
Per cent. of sand in dried cake,	36.02	35.23	37.82	38.04
Ratio sand to slime, 1 to, .	1.77	1.83	1.64	1.62
Average sp. gr., 1.804.	Average percentage of water, 29.71.			
CAKE G.				
Specific gravity of cake, .	1.776	1.814	1.853	1.841
Per cent. of water,	30.0	28.4	26.9	27.4
Per cent. of sand in dried cake,	51.6	54.0	53.7	50.1
Ratio sand to slime, 1 to, .	1.08	1.10	1.17	1.22
Average sp. gr., 1.821.	Average percentage of water, 28.4.			

Comparing the results in Table I. with those given for the type slime, a variation in water-content of from 38.1 to 28.4 per cent., and in density of from 1.632 to 1.821, is shown for a variation in sand of from 6 to 52 per cent. The sand in these cakes was determined on the basis of 1-min. settlement. An increase in the proportion of fine sand decreases the interstitial space, but does not decrease the permeability, as the curves for filtering-rates show. For purposes of comparison the proportion of water absorbed by fine sands is shown in Fig. 12. Fine sands (quartz) between 80- and 100-mesh contain 26.4, and for sands passing a 200-mesh screen and from which all slime was elutriated, 28.1 per cent. of water. The volume relationship is also shown for both fine sands and slime in Fig. 12. The former shows 47.7 of water and 52.3 per cent. of solid; the latter, 60 of water and 40 of solid. These figures are of interest in that they show the comparatively large volume-proportion of water in the slime-cakes.

ive results between sand and slime show that the water is no indication of the permeability of a al.

H shows the results for the Virginia City slime; the slime built up under 21.7-in. vacuum (36.2 moisture and 1.662 sp. gr.); *J* shows the same

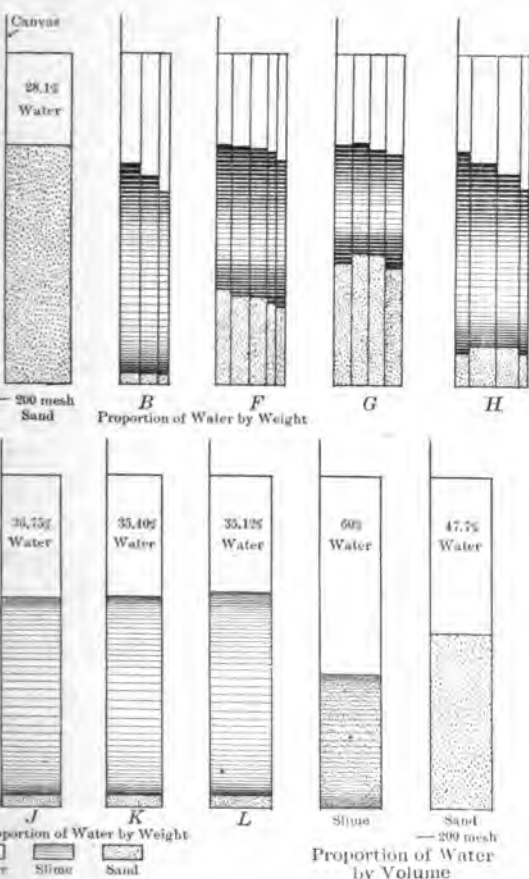


FIG. 12.—SECTIONS OF SLIME-CAKES.

under 11.35-in. vacuum (36.75 per cent. of moisture and 1.675 sp. gr.); *K* shows the same slime built up under 21.8-in. vacuum (35.12 per cent. of moisture and 1.683 sp. gr.).

Fig. 12 serve also to show the effect of pressure

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upon the specific gravity of the slime-cake. To these may be added a slime-cake from the type slime which was built up on a slat-supported filter of No. 12 duck, giving with 21.5-in. vacuum a moisture-content of 33.6 per cent. and specific gravity of 1.71; and a cake built up under 30 lb. of air-pressure, giving 28.1 per cent. of moisture and 1.805 sp. gr. With the exception of *K*, there is an increase in the specific gravity with an increase of pressure. This increase in the density of the cake means a decrease in the permeability, and therefore a decrease in filtering-rate. A slime-cake may be likened to a number of layers of rubber spheres. Pressures great enough to overcome the elasticity of the spheres would have the effect of squeezing them into spheroids and reducing the interstitial space; still greater pressures would cause the spheroids to encroach upon the open spaces until these would be practically closed and the interstitial space become zero. The difficulties involved in using high pressures upon slime carrying a minimum proportion of sand are apparent. The effect of the presence of sand would be the same as if angular grains were mixed with the rubber spheres. Under pressure the angular grains would press against one another and prevent any great degree of pressure coming upon the spheres. There would be a comparatively small decrease in the interstitial space, and therefore little or no reduction in permeability.

An interesting phenomenon was noticed in transferring slime-cakes. The lifting of the cake from the pulp was accompanied by an immediate shrinkage in the thickness of the cake. The reduction in thickness amounted to from 10 to 12 per cent. On submerging the cake in the pulp the original thickness would be approximately resumed. The effect of the shrinkage is to increase the density and decrease the filtering-rate. With sand-slime cakes no noticeable shrinkage was observed until the cake approximated a thickness of 1 in., and in all cases this shrinkage was less than that of the-slime cake. During the building up of a slime-cake there is a progressive densification, somewhat slow and often irregular, which accounts for the erratic results obtained in some cases with the filtering-rate experiments.

The progressive densification of a slime-cake may be shown in another way. Subjecting a thick slime-cake to continued



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is immersed in water, and determining the filter-overal successive time-intervals, gives a slow drop g-rate.

Temperature has a slight effect in increasing the cake, but the experiments on this point were on somewhat inconclusive.

Building of a slime-cake takes place under two conditions: it is removed from the pulp and allowed to remain under full pressure, and when removed from a pulp at a temperature 40° or 50° C. higher than the pulp. The latter condition is of little practical importance. The cake can be overcome by reducing the vacuum-pressure to just enough to hold the cake upon the cloth. Too long an exposure to this pressure will cause a cake to crack. Under a vacuum of 21 in. a 1-in. cake will break down in from 10 to 15 minutes.

Sand-slime cakes will stand a longer exposure to vacuum. The cause of cracking is lateral shrinkage, due to displacement of the water by air and air-drying.

Building up cakes with vertically-suspended filtering-cloths has a tendency for the cake to build up thicker at the top. This is due to the increase of filtering-pressure with increased hydrostatic head, and also to the thickening of the pulp in the lower part of the filter-vat. Agitation of the cake to a large extent, the building up of thick-ended cakes where the proportion of sand is large and the sand is coarse, agitation is quite necessary, but should not be too violent, as otherwise the building up of a cake would be interfered with by erosion. With fine sands, finer screens, if a pulp-density of 1.4 or more is maintained, or no trouble is experienced by the sands settling out of the pulp, in the experiments, remained quite clear for intervals of longer than one hour. With a high proportion of water in the pulp moderate agitation is sufficient in most cases.

Cakes should be built up with vacuum-pressures as low as possible, and should be kept completely submerged until the cake is forming. The temperature of the pulp and the water should be the same. Transfers from pulp to filter should be made as rapidly as possible and under reduced vacuum. Filters in which the transfers are quickly

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made, and with the minimum of exposure of the cake to the air, are more efficient and maintain a higher filtering-rate than those in which long time-intervals are required for the necessary transfers.

Building Up Slime-Cakes.

Three direct factors control the rate of and the total time required for building up the cake: the thickness of the cake, the filtering-rate of the slime, and the proportion of water in the pulp. Indirectly, temperature, viscosity of the pulp, intensity of the vacuum used, depth of submersion of the cell, agitation, and the physical character of the slime, play a part in the building up of the cake. The effect of the indirect factors is summed up in the filtering-rate.

Practical experience has placed certain well-defined limits upon the thickness of the slime-cake. For example, the Ridgway filter utilizes a thickness of from 0.125 to 0.375 in.; the Oliver, from 0.25 to 0.5; the Butters and Moore, from 0.75 to 1.75; the Merrill, from 1.75 to 2; the Kelly, from 1 to 3, and the Burt revolving-filter, up to 6 in. With vertically-suspended filters the thick cakes tend to tear apart and drop during the transfers. The thickness of the cake also determines the time required for washing. Thick cakes require relatively a much longer time to wash than the thin, on account of the low filtering-rates, and the capacity of a filtering-unit may be very greatly cut down. With slime-cakes the lower limits mentioned above are used; with sand-slime cakes the upper limits may be used.

Other things being equal, the less solution that is required to be drawn through a filter in the building up of the cake the more quickly the cake will be secured, and consequently it is desirable to have the slime-pulp as low in content of water as possible. There is a practical limit to the thickening of the slime-pulp, and this is established by the settling-power of the pulp and the fluidity of the settled pulp. The settled pulp must be handled in pipes and with centrifugal pumps, and if it is too thick it becomes impossible to do this. A thick pulp is advantageous where much sand is to be held in suspension. In Nevada, with quartzose ores, pulp-ratios of from 3 of solution to 1 of slime down to 1.5 of solution to 1 of slime are in use. The average pulp in use is 2 of solution to 1 of slime.



M



M



the relation between percentage of water and
 of slime-pulp and cakes for a slime of specific
 Similar curves may be worked out for slimes of
 specific gravity.



RELATION BETWEEN PERCENTAGE OF MOISTURE AND SPECIFIC GRAVITY.

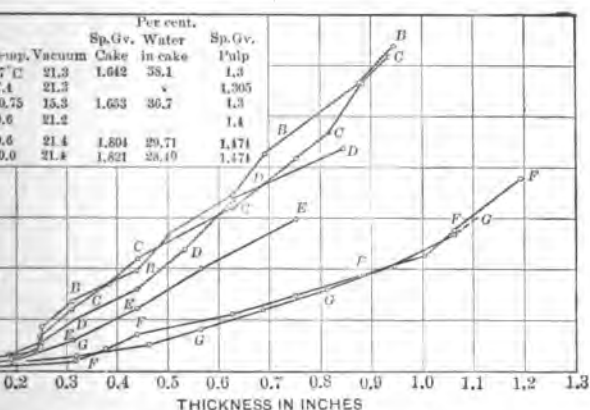


FIG. 1.—RATIO OF BUILDING UP CAKES, No. 10 CANVAS.

shows the rate of building up slime-cakes on No. 10
 curves B, C, D, E are for the type slime; curves F
 for the type slime with mixtures of sand to the

amount of 37 and 52 per cent., respectively. Curves *B* and *C* show a rapid consolidation of the cake at 0.25 in. thick, and then a gradual thickening. Curve *D*, built up at a lower pressure, shows a gradual thickening and a somewhat greater rate of thickening than *B* or *C*. Curve *E* shows a greater rate of

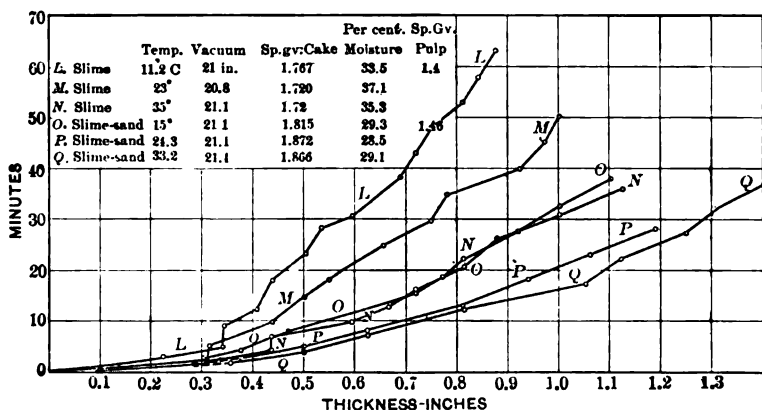


FIG. 15.—RATE OF BUILDING UP CAKES, No. 12 DUCK.

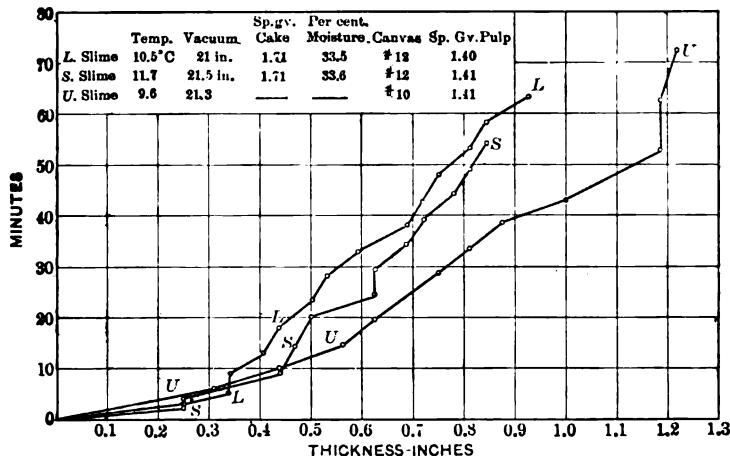


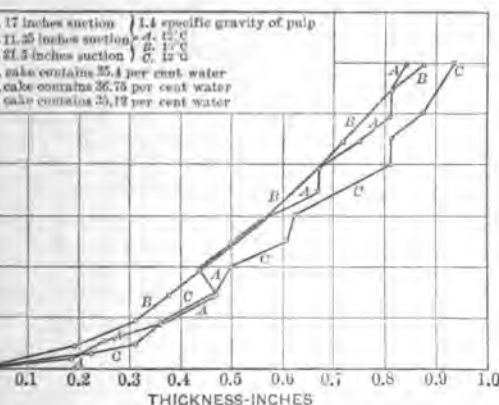
FIG. 16.—RATE OF BUILDING UP SLIME-CAKES.

thickening on account of the greater density of the pulp. The curves for the sand-slime cakes show a gradual thickening.

Fig. 15 shows the rate of building up slime and sand-slime cakes on No. 12 duck under different temperature-conditions. Curves *L*, *M*, and *N* are for the type slime, and *O*, *P*, and *Q*

containing 52 per cent. of sand. All three slime-cakes greater irregularities than the sand-slime, and the variation of the slime-cakes between 0.3 and 0.45 is characteristic. Increase of temperature in rate of building up to a marked extent.

of using a more permeable filter is illustrated by Figs. 14 and 15. The significant curves are shown in Fig. 14. Curve *L* is the type slime built up on No. 12 duck cloth; curve *S* is the type slime built up on the grooved board; curve *T* is the type slime built up on No. 12 canvas and diamond-strip support. The results show faster rates for the thin cakes and for the thick cakes than the less permeable filter with No. 10 diamond-strip-supported filter gives a faster rate on the grooved board.



BUILDING UP OF CAKE UNDER VARYING PRESSURES.

shows the effect of pressure upon the rate of building up the slime and No. 10 duck were used in these experiments. Curve *B*, the rate-curve for the lowest pressure, is the slowest; curve *A* is broken, and shows three consolidation stages; curve *C* shows corresponding but not such prominent stages. The curves, on the whole, indicate that increase of pressure, other things being equal, will increase the rate of building up.

shows the rate of building up a slime-cake from a mixture of fire-clay. The very slow rate and the four

pronounced consolidations extending over comparatively long time intervals are of interest.

The rate-curves indicate that as a slime-cake builds up a slow consolidation takes place, and superimposed upon this is an irregular and faster rate of consolidation. The irregular consolidation is characteristic of very slimy and clayey slimes, and becomes less so as the proportion of sand is increased. The sand diminishes the elastic nature of the slime-cake.

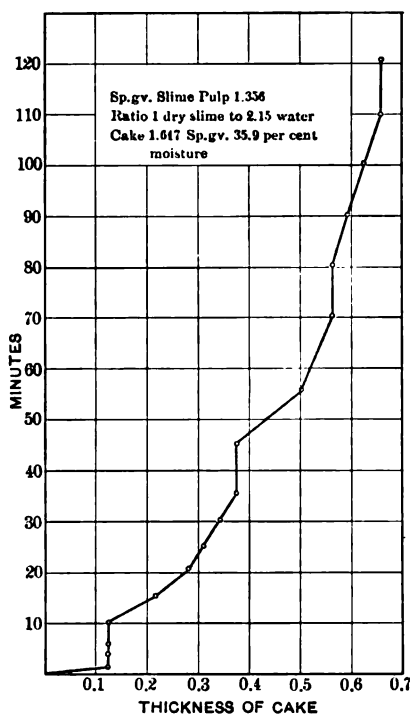


FIG. 18.—BUILDING UP CLAY SLIME.

Washing.

A slime-cake retains from 28 to 38 per cent. of solution; the former for sand-slime and the latter for slime-cakes. Were it not for osmosis, simple displacement with a volume of water equal to that retained by the cake would be sufficient to remove the dissolved salts of gold, silver, and cyanide. As it is, the soluble salts diffuse back into the wash-water, and in time this builds up in gold- and silver-values to such an extent that an appreciable loss results when, as in the Butters filter, the slime-

out with the residual wash-water. By the use of wash-solutions this difficulty can be more or less overcome, but it has the objection that an additional filtration and exposure of the slime-cake to the air is required. With the Moore, Oliver, and the pressure-filter no great trouble is experienced from loss of wash-solution, for in each case only that wash-solution is left in the cake after air-displacement takes place, and this amounts to from 20 to 30 per cent. It is customary to use barren solution or wash-water to from one to three times the amount of solution retained in the cake. With very low-grade solutions the high-grade solutions the latter, would be used. The amount of the solution retained by the cake is usually less than the values retained by the solution in

the process of washing is determined largely by the value of the gold, silver, and cyanide remaining. When the cost of recovery, washing stops.

It is noted that with the thin-cake filtering-appliances a smaller amount of wash-water would be required than for the thicker cakes, for the reason that the rate of filtration is higher with the former. Strength of solution, time, and pressure are the controlling factors in osmosis; and of these perhaps the most important; for the other two are the same in either case. The shortness of the time required for washing and the relatively high filtering-rate in the Oliver filter would give little opportunity for loss of solution with the washing.

Experiments were made with suction-filters. A series of experiments were made with a pressure-filter in washing solutions containing cyanide. With pressures varying from 0.1 to 0.2 lb., and with a 0.2-per cent. cyanide solution, it was required from 1.3 to 1.4 times the contained cyanide to remove the cyanide-content to 0.02 per cent.

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Complete Cycle of Filtration.

Given the time for making all of the necessary transfers, the time for a complete cycle of operations may be approximated by using the filtering and building-up rate-curves. Two such examples have been worked out in Figs. 19 and 20. The former shows the time required for a complete cycle for the type slime, mixed with 50 per cent. of sand, both for single

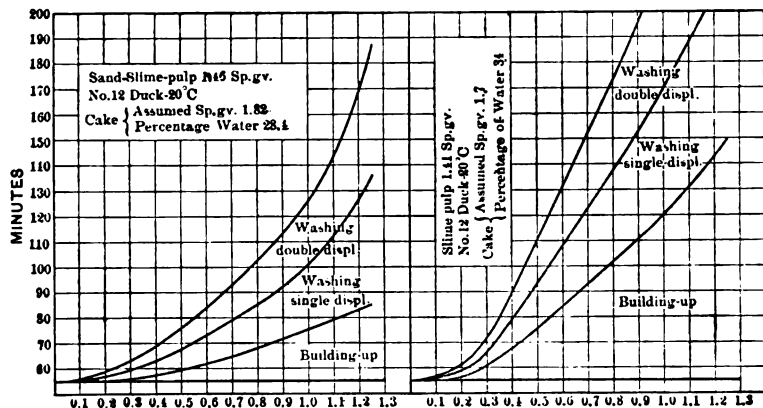


FIG. 19.—CHANGES-TRANSFERS.

FIG. 20.—CHANGES-TRANSFERS.

displacement and double displacement; while the latter shows the time required for the type slime. The 24-hr. capacity per 100 sq. ft. of filtering-surface may be calculated from the diagram, and the specific gravity of the cake and the percentage of moisture retained. Table II. shows the results of such calculations.

Filtration: Capacity Per 100 Sq. Ft. of Filtering-Surface Per 24 Hr.

SAND-SLIME CAKE.

	0.25 In.	0.5 In.	0.75 In.	1 In.	1.25 In.
cake, pounds (per 100 sq. ft.)	236	473	710	947	1,183
slime, pounds	170	340	510	681	851
cycles,	24	20.8	17.5	14.2	10.5
single displacement,	2.04	3.54	4.46	4.83	4.46
cycles double displacement,	23.6	18.7	14.6	11.4	7.6
cycles,	2.0	3.2	3.7	3.88	3.2

SLIME-CAKE.

	0.25 In.	0.5 In.	0.75 In.	1 In.	1.25 In.
cake, pounds (per 100 sq. ft.)	221	442	663	885	1,016
slime, pounds	146	292	438	585	731
cycles single displacement,	22.8	15.1	11	8.4	6.7
cycles,	1.6	2.2	2.4	2.45	2.38
cycles double displacement,	21.8	14.1	8.7	6.5	5.1
cycles,	1.5	2.04	1.9	1.9	1.8

constructed for a Butters filter, and the time for each cycle is taken as 55 min. These data clearly show the feasibility of using thin cakes for filters of this type. When the costs into account, it is advisable to have as few cycles as possible in filters of the Butters type, and this would be accomplished by building up thick cakes.

It is noted that the capacities calculated are higher than those that pertain in practice, for the reason that the amount of pulp than is ordinarily the custom was used and that the time for building up was less.

For a different horizontal axis in Figs. 19 and 20, the calculations for a complete cycle for other suction-filters may be made by the same calculations made for capacity.

Data from Slime-Plants.

secured from a number of slime-plants in Nevada courtesy of the different managers. Table III. results of a number of physical analyses of slimes from these plants. For purposes of comparison the sand-slime mixture, the clay slime, and the mill-slime are included in the table. The screen-analysis is as follows: A 50-g. sample was taken and mixed in a mortar to a thin pulp and then poured into an 8-oz. beaker and sufficient water added to make a volume of approximately a ratio of 1 of slime to 12 of water. The contents of beaker No. 1 was allowed to stand 2 min. and then poured into a beaker of the same size. The sand from the bottom was mixed with 600 cc. of water; allowed to stand 2 min.; contents of beaker No. 2 were then poured into beaker No. 3 and of No. 1 into beaker No. 2; after standing 2 min. contents of No. 3 were poured into No. 4, of No. 2 into No. 3, and of No. 1 into No. 2. No. 1 was filled with water and allowed to stand 2 min. Contents of beaker No. 1 were poured into a 1.5-l. beaker, of No. 3 into No. 4, of No. 2 into No. 3, and of No. 1 into No. 2. No. 1 was left empty and the reject in two 1.5-l. beakers. The sands from the pans were dried and then screen-analyzed on 150- and 200-mesh screens. The portion of the large beakers was stirred and allowed to settle and the supernatant liquid poured off; the sands constituted the 4-min. portion and standing 8 min. gave the next to the last portion and the last portion constituted the remainder. The slimes obtained by this method were clean and free from adhering sand. The residue was almost all silica. The size of the grains of the slimes was approximated by measurement with

micrometer and the clay slimes stand out conspicuously. The mill-slime mixed with 50 per cent. of sand and the mill-slimes were analyzed closely. Pulp *F* is a concentrate treated by pressure-filtration in a Kelley filter. Practically all pulp considered as slime passes a 100-mesh screen. The residue is finer than a No. 150 screen and 79 per cent. is finer than a No. 200 screen. The fine portion which

takes more than 8 min. to settle gives an average of 27.5 per cent. for the mill-pulps. The chemical investigation was not completed, but the results of partial analyses are sufficiently interesting to include. With two exceptions, the type slime and mill-slime *C*, the calculated percentage of aluminum silicate corresponds approximately with the portion of the pulp taking longer than 8 min. to settle. Microscopical examination of the coarser portions show them to consist almost entirely of silica. The results on the type slime indicate that considerable silica remains with the last portion of the slime. Slime *C* is from the Goldfield Consolidated mill; as is well known, part of the alumina is present as alunite, and consequently the calculation of all of the alumina to aluminium silicate gives a result too high. The results of the chemical analyses indicate that by combining physical and chemical methods an approximate separation and quantitative determination of crystalline and colloidal material may be effected.

Table IV. gives the data of the slime-plants from which the mill-slimes in Table III. were taken.

TABLE IV.—*Details of Slime-Plants.*

	A. Butters.	B. Butters.	C. Butters.	D. Butters.	E. Merrill.	F. Kelley.	G. Butters.
Type of filter, . . .	2	2	2	2	3	1	1
Number of units, . .							
Number of leaves per unit,	60	95	168	72	64	10	100
Number of leaves, . .	120	190	336	100	192	.....	100
Area of leaf, sq. ft., .	100	91	100	92.6	41.4	.....	100
Total filtering-area, .	12,000	17,290	33,600	9,282	7,980	860	10,000
Tons slime per 24 hr.,	175	250	1,000	150	216	100	180
Tons slime per 100 sq. ft. per 24 hr., . .	1.4	1.44	2.97	1.62	2.72	27.7	1.5
Slime-pulp consistency, water : slime,	3:1	3:1	1.5:1	2:1	2:1	1:1	2:1
Filter-support, . . .	slats	slats	matting	slats	plate	wire netting	slats
Thickness of cake, in.,	1	0.75-1	1.25-1.75	1.25	1.75	1.5-2	1.5
Moisture in cake, p.c.,	38	35	35	33	.....	12	29
Time forming, hr., . .	1	0.5	1-1.33	1	0.66	0.03	2
Time washing, hr., . .	1	1.0	1.41-1.66	1.25	0.41	0.20	2
Time transfers, hr., . .	0.75	0.83	0.59-0.51	0.5	3.01	.....	1.88
Total time-cycle, hr.,	2.75	2.33	3-3.5	2.75	4.08	0.5-0.75	5.88
Filtering-rate per 100 sq. ft. per min., . .	11.6	26	8.3	6.88	30	.....	.....
Filtering-rate per min. for wash, . .	10	16.8	.....	.....	.....	.....	.....
Tons of solution and wash per 24 hr., . .	848	1,356	2,000	350-400	328 340	*75	484
Canvas used, oz., . .	12	12	12	12	18	12	10
Life of canvas, months,	8	6	41 est.	18	12	0.5-1.5	.....
Frequency of acid-wash, days,	20	21	30	21	60	15	30
Approximate cost per ton slime,	\$0.18	\$0.27	\$0.075	\$0.25	\$0.288	\$0.85	\$0.119

* 8-12 hrs.

[32]

Conclusions.

tical conclusions may be drawn from the experiments. These have been in part stated, but may not be complete, together with certain general conclusions so directly shown by the experimental work.

Proportion of clayey material in ores which are to be "all-sliming" and filtration should be maintained

Slime-pulp should be as free as possible from sands No. 150 screen, and as large a proportion of the pulp should consist of material passing a No. 200

Slime-pulp before filtration should be settled to as thick as possible consistent with ready handling by pipes.

Temperature of the slime-pulp should be maintained at 30° C. or higher.

Temperature of the wash-water and the pulp should

Pressures should be varied until the proper ingoing slime is obtained.

Every clayey slime is to be filtered, as much fine sand (as stated above) should be crowded into the pulp without undue settling and clogging.

Canvas supported by slats gives the best all-round thick cake, and No. 12 canvas on wire netting meets requirements for the thin-cake filtering-machines.

Filters containing a large proportion of colloid or fine sand at pressures greater than those obtainable with vacuum are of questionable advantage.

Filters containing a large proportion of clayey material vacuum-filters should be used.

Filters containing a small proportion of clayey material much fine sand both vacuum-filters and pressure-filters used with perhaps equally good results.

Filters containing much coarse and fine sand the best results with air-agitation and high pressures would be the best results.

13. Of the vacuum-filters, the thin-cake continuous filters are a decided improvement over the thick-cake filters.

Acknowledgments.

I am especially indebted to many of the students of the Mackay School of Mines, to Jay A. Carpenter, to W. S. Palmer, and to many of the superintendents and managers of milling-plants in Nevada for assistance and data. In closing this paper I wish to express regret for my inability, on account of the pressure of other duties, to carry out more completely closely-related lines suggested by the experimental work.

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TIME-FILTRATION

BY

GEORGE J. YOUNG

Mackay School of Mines

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MANGANESE

INTRODUCTION

is issued for the purpose of stimulating prospecting and possible sources of manganese in Nevada. We do the big things in the war, some of the smaller, but things are possibly overlooked. We do not realize the little that we can do. For example, the supplying of rare or uncommon metals, which in ordinary times necessary, at this time may become a vital factor for the conduct of the war. At this time, more than at any other time, we need to develop our own natural resources and which can be produced from within our own borders. We need for other service ships which are so much needed at this time. Production from our own resources, taken up as a war effort, may develop new lines of industry for times after

NEED OF MANGANESE

one of these metals. It is absolutely essential for the production of high-grade steel. A recent statement of Secretary Frank B. Rowland of the Interior Department is to the effect that 50,000 tons of manganese are now necessary to supply the demands of the steel industry with manganese, imported from Brazil, and that, if a sufficient quantity could be released, it would be capable of carrying 300,000 tons of material annually to Europe.

MANGANESE DEPOSITS

ores occur in many parts of the United States, and in some have been exploited to a certain extent. The deposits, however, are small as compared with certain foreign ones and, due to various conditions, have not been developed more extensively. Some of the conditions have been: location of the markets in the East, the need of paying high freight rates in comparison with those of the ore, uncertainty of payments after shipment, the presence of certain impurities on the value of the ore, and the amount of ore demanded. These conditions have been greatly changed since the war started. We divide our manganese deposits in three general classes: high-grade manganese ore chiefly valuable for manganese; manganese silver ores; and manganese iron ores.

deposits in the United States are secondary and have the concentration of manganese originally occurring in them, more widely distributed in adjoining rocks. In general, these deposits are of comparatively slight depth, often consist of pockets of good ore, but widely scattered over considerable areas and therefore require careful study to determine their possibilities.

MANGANESE IN NEVADA

has not been formerly looked on as a promising State for manganese. Some good though small deposits have been found. At various places there are examples of the first class of deposits. Some very good ones have been found. These deposits have been described briefly

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by E. C. Harder.* They are believed to consist of deposits formed from waters issuing from surrounding sedimentary rocks, and occur interstratified with silicious and calcareous tufa in a bedded deposit. At Pioche we have examples of the third class of deposits. A recent estimate of the Geological Survey places the probable ore in two Pioche deposits at 550,000 tons and possible ore at 1,000,000 tons, carrying approximately 12% manganese, 34% iron, 13% silica, and less than 0.1% phosphorus. While this type of ore has up to the present time been used only to a limited extent, more use may be made of it in the near future.

In view of the fact that little attention has been paid to this metal in the past, the extent of the mineralized sections of the State, and its common association with silver deposits, it is not unlikely that there may be many good deposits found here in Nevada. Recently very encouraging reports have come of new discoveries in different parts of the State, especially from near Las Vegas, Ely, and Golconda. The latest reports from Las Vegas indicate there are being shipped 60 tons daily with hopes of increasing this soon to 200 tons. Reports from Ely state they are making daily shipments of 20 to 25 tons and with improved transportation can increase this amount. If shipments of 220 tons daily could be maintained, they would have considerable influence on the general situation. In round figures they would total \$1,000 tons yearly, and, as the estimated amount imported last year has been placed at about 500,000 tons, it is readily seen what an appreciable effect the Nevada supply would have.

The Mackay School of Mines has recently received from a number of different localities in the State very good samples of manganese ore. Attention should be directed first to securing ores of shipping grade without preliminary treatment. Some concentrating tests have been made to improve the grade of some of the low-grade silica-bearing ores with promising results. The Mackay School of Mines proposes to make further tests on this type of ore during the summer.

MANGANESE MINERALS

While there are many manganese minerals, there are only a very few commercially valuable. A few simple tests will serve to identify them. The oxides all have a dark color and streak; when fused with borax give an amethystine-colored bead; when fused with soda and niter give a greenish-colored bead; treated with hydrochloric acid give off chlorine gas.

The following are the chief minerals with a brief description of each:

Pyrolusite.

This mineral is sometimes called "black oxide of manganese." Its composition is manganese dioxide, containing 63.2% metallic manganese. It is a soft black mineral having a metallic to dull luster, usually soft enough to soil the fingers; occurs massive, compact, stalactine, and as crusts; its powder is black and its color black to steel-gray; gives an amethystine-colored bead when fused with borax; is soluble in hydrofluoric acid liberating chlorine. It occurs in this State in several localities: Las Vegas, Ely, Golconda, and near Schurz.

Psilomelane.

This mineral does not have a definite composition, but the content of

*See "References" at end of this pamphlet.

ally high, not, however, as high as pyrolusite. In pyrolusite, but is very much harder, being 4 to 5, as 1 to 2.5; it is never crystallized; occurs as a massive mineral; it is infusible; generally yields water on heating; gives reactions with hydrochloric acid and borax bead. It is usually associated with pyrolusite, and in some localities, as at Golconda.

a manganese oxide of the composition Mn_2O_3 ; hard-metallic luster; brownish-black to steel-gray color; similar to pyrolusite with borax and hydrochloric acid.

a hydrated form of the oxide, containing, when pure, 14% water; occurs as long and short prismatic crystals; has a steel-gray to black color; reddish-brown to black on heating; gives reactions with borax and hydrochloric acid similar to

a carbonate, containing, when pure, 61.7% manganese; pink to brownish-red and brown; occurs massive, granular; hardness, 3.5 to 4.5; is transparent to opaque; colorless, but changes dark-colored under the blowpipe; gives a dark-colored bead with borax; is soluble in warm hydrochloric acid with effervescence; shows cleavage parallel to the rhombohedron in this State at Austin.

the manganese silicate. The pure mineral would be a commercial ore, due to the presence of silica. It is generally brownish-red in color; hardness, 5.5 to 6.5; gives reactions with borax. It is found in this State near Golconda.

a mixture of manganese oxides, together with the other metals, notably copper, lead, and cobalt; color black; varies in hardness from 1 to 6; gives with borax reactions as pyrolusite and also often will give tests for iron and cobalt.

COMMERCIAL ORES

Several factors which determine commercial or shipping value are influenced by the use to which the ore is to be put. For example, a different grade is desired for use in making dry batteries than for making of ferromanganese for use in steel. Following are the limiting conditions which the manganese ore must meet for use in the steel industry:

1. In metallic manganese must run over 38%, and a premium is paid on ores as the content of manganese rises. It is generally required that the content of manganese run over 40%.
2. The content of the ore should run less than 8% iron, although as high as 12% will be accepted by some buyers and up to 15% in some cases. These penalties are referred to

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later in this report. Silica is objectionable, due to its tendency to produce a large volume of slag and also to carry manganese into the slag when smelted.

3. Phosphorus is not eliminated in smelting manganese ore, and therefore limited to a very small amount in commercial ore. In general, the ore must contain less than 0.20% phosphorus.

4. Ore to be used in making ferromanganese must contain less than 8% iron. This is necessary in order to produce an alloy running 80% manganese. The lower the iron the more desirable the ore.

Some of the samples sent to the laboratory have shown on analysis up to 3% tungsten as the trioxide. Inquiry has been made regarding its possible influence on the value of the ore. With one exception, the replies indicate that, while it is not detrimental, neither is it thought that any return could be made for the contained tungsten. One dealer stated the tungsten would detract from the value of the ore for its purpose.

As some of the Nevada ore has shown sulphur in the form of barium, sodium and calcium sulphates, inquiry has been made as to the allowable amount of sulphur, and this has been fixed by one dealer at from 1% to 2% and the ore still be of value in steel manufacture.

CHEMICAL ORE

For use in making dry batteries, glass, and in the enameling industry the highest grade ore is required. It is then called "chemical ore." This type of ore commands a slightly higher price than "metallurgical ore." It must contain high manganese, preferably about 50% metallic manganese, less than 1½% iron, and less than 0.01% copper. Some of this grade has been found in Nevada, but in general the western ores contain too much iron or copper for this classification.

MANGANESE IN STEEL

Manganese, to become useful for the steel industry, must first be produced in the form of an iron-manganese alloy. If this alloy contains under 20% manganese, it is known as spiegeleisen; if it contains between 20 and 80%, it is known as ferromanganese. The higher grade alloy is demanded by the steel industry, and up to the present time the demand has been satisfied. In the attempt to use the manganese iron ores which occur in large amounts in this country, the lower grade alloy may come into more extended use.

Spiegeleisen is usually produced by smelting a manganese iron ore in the blast furnace. Lime is the principal flux. Silica is objectionable owing to its tendency to produce a large volume of slag and at the same time carry away with it large amounts of manganese. Ferromanganese is produced by smelting a high-grade manganese ore in the blast furnace or in the electric furnace.

Manganese is used in steel for the following reasons:

First—To neutralize the harmful effects of sulphur by the formation of the less harmful sulphide of manganese.

Second—To remove oxygen from the steel and prevent thereby the formation of blowholes.

Third—To produce the special alloy steel known as manganese steel used for implements or parts of machinery subject to great wear, crushing surfaces of ore-crushers, parts of plows, rails for curves on street railways where subject to heavy use, and burglar-proof safes.



BUYERS OF MANGANESE ORE

There is only one firm which will buy manganese ore—Purchasing Company of Reno. Other firms outside purchase ores. In a recent bulletin issued by the United States Geological Survey a list of purchasers of manganese ore is given. This bulletin has been reprinted in the Engineering and Mining Journal, January 26, 1918. These firms will buy the following ores:

- 1. 0% manganese ore, less than 2% iron.
- 2. 0% manganese ore, more than 2% iron.
- 3. 5 to 40% manganese ore.
- 4. 5 to 15% manganese ore.

Ores 3 and 4 probably apply the usual restrictions on the phosphorus given below.

SCHEDULE OF PRICES

The present custom of purchasing and prices paid for it is necessary to give what is called a price schedule. Any such price schedules are always subject to the changes in the market prices. The latest quotations are given in such weekly periodicals as the Engineering and Mining Journal and the Mining and Scientific Press.

This is an approximate schedule of present prevailing prices for manganese ores ranging from 38 to 50% and above, in pure manganese. From 90 cents to \$1.10 per unit of pure manganese, found in a long ton of 2,240 pounds. These quotations are for ores from the eastern Pennsylvania points. They are based on a sample dried at 212°F. Allowance is to be made, of course, for moisture in the ore, as determined by analysis at the given temperature.

The following figures will illustrate the application of this price schedule. If the ore is the same as 1% metallic manganese, thus a manganese ore of 1% manganese would contain one unit of manganese in a long ton of 2,240 pounds, it would weigh 22.4 pounds, as given above. A 50% ore would be worth 50 units of manganese. The price paid for a 50% ore per unit would make the value of such an ore \$55 per long ton. If a sliding schedule is used, a 38% would be figured as 38 units of manganese and in this case it would be worth the lower figure stated above, or 90 cents; the ore would be 90 cents times 38 or \$34.20 per long ton. Between 38 and 50% manganese will have a rate per unit between 90 cents and \$1.10, according to the per cent of manganese. Ore above 50% manganese will bear the \$1.10

For each 1% silica in excess of 8% there will be a penalty of 50 cents per gross ton. For each 0.01% of phosphorus in excess of 0.01% there will be a penalty assessed of 50 cents per gross ton.

For each 1% of silica under 8% there will be a premium of 50 cents per gross ton, provided the manganese content goes

Ores containing more than 15% silica, or over 0.20%

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phosphorus, or less than 38% manganese, is subject to refusal or rejection at the buyer's option.

It might be of interest to Nevada prospectors to know that the Western Ore Purchasing Company will sample and purchase manganese ores in less than carload lots, which will enable them to obtain money with which to develop their property without delay.

FREIGHT RATES

The following freight rates have been supplied by the Southern Pacific Company as in effect at this time, March 29, 1918. These rates are per ton of 2,000 pounds. It should be noted that manganese is usually purchased, however, on the long-ton basis of 2,240 pounds, and allowance should be made for this fact in estimating the value of ore in a given case:

Golconda to Hazen.....	Value \$50, \$1.45 per ton ; Value \$100, \$2.20 per ton
Reno to Hazen.....	Value \$50, \$0.60 per ton ; Value \$100, \$0.90 per ton
Schurz to Hazen.....	Value \$50, \$0.60 per ton ; Value \$100, \$0.90 per ton
Hazen to Pittsburg.....	No value stated, \$11.00 per ton
Hazen to Chicago.....	No value stated, \$9.00 per ton

EXAMINATION OF SAMPLES

Samples of supposed manganese ore will be examined and tested free at the Mackay School of Mines if the samples sent are from within Nevada and are taken by residents of this State.

The School will gladly furnish further information on this subject to any person desiring the same.

The School will also appreciate any information regarding manganese deposits in this State, names of shippers or possible shippers, and any local problems in connection with increasing present shipments.

REFERENCES

"Manganese Deposits of the United States with Sections on Foreign Deposits, Chemistry, and Uses" (U. S. Geological Survey Bulletin No. 427, by E. C. Harder) is the best and most concise reference on the subject up to 1910.

"The Mineral Industry," issued annually by McGraw-Hill & Co. and "The Mineral Resources," issued annually by the U. S. Geological Survey, will bring the subject up to date.

"Metallurgy of Iron and Steel," by Bradley Stoughton, formerly a Professor of Metallurgy in Columbia School of Mines, and now the Secretary of the American Institute of Mining Engineers, is a good reference on the use of manganese in steel.

"Prospecting for Manganese," by Henry V. Maxwell, is a short interesting article appearing in the Engineering and Mining Journal for February 9, 1918.

In the September (1917) Bulletin of the American Institute of Mining Engineering is found a review of the New York Section's War Meeting on Manganese. This account gives the best present review of the subject as influenced by war conditions.

Bulletins have already been issued along similar lines to this by the State Mineralogist of California, and the Colorado School of Mines.

UNIVERSITY OF NEVADA BULLETIN

FEBRUARY 16, 1928

No. 2

A TABLE FOR THE
IDENTIFICATION OF NEVADA'S
COMMON MINERALS

with Notes on Their Occurrence and Use

—PREPARED BY—

THE HACEY SCHOOL OF MINES

AND

THE STATE MINING LABORATORY

BY

JOHN R. GRAVE



ON STAMPESS TO THE UNIVERSITY OF NEVADA
RECEIVED 1928

This volume of 215 pages, containing 40 illustrations, is a valuable
reference work for the student and the professional geologist. It
contains a complete list of the minerals occurring in Nevada, and
describes their occurrence and use. It is a valuable addition to the
library of every geologist.

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UNIVERSITY OF NEVADA BULLETIN

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No. 1

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PUBLISHED QUARTERLY

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DESCRIPTION OF NEVADA'S COMMON MINERALS

THE COMPOSITION OF THE EARTH

appears to be a complex aggregate of material varying in place to place. A gold mine is discovered here, gypsum while over most of the earth many kinds of barren rock heterogeneity is more apparent than real, however, for the geologist with the utmost patience and skill, has found that all parts of our earth, land, sea, and air, are made up of ninety-two elementary building materials. These he calls *elements* for brevity designates each by a *symbol*. Out of these thousands of combinations have been made in nature. Around certain elements are combined in definite proportions which the chemist indicates briefly in a *formula*. Thus, water to contain two units of hydrogen and only one of oxygen he indicates by the formula H_2O , but since the building material weighs sixteen times as much as one of hydrogen, water is actually eight times as much oxygen as hydrogen or eight-ninths or 88.8% oxygen and only one-ninth or 11.2% hydrogen. A *mineral* is just such a chemical compound which has been formed by natural processes. Each mineral, therefore, when pure, contains a certain per cent of each of its component elements. A *simple mineral* are themselves elementary and hence the element is said to be in its *native* state. Native gold and silver are examples. Other minerals are highly complex. Some minerals can be profitably mined where the percentage of gangue or waste material is large, while others are commercially useless if only small amounts of the mineral are present. In general, nonmetallic deposits must be much larger than metallic deposits. Rock which averages less than 1% of occurring in workable quantity, can be considered gold ore. 10 per cent of quartz in dumortierite will render dumortierite as a porcelain-making mineral.

All sorts of inorganic earth material, minerals, rocks, and fossils further indicate the simplicity of our earth, for of the ninety-two elements, twelve make up over ninety-nine per cent of the earth. W. Clarke (*The Data of Geochemistry*, U. S. Geol. Survey, 1924, p. 36, 1924) gives the following average percentages of elements in known terrestrial matter:

<i>Symbol</i>	<i>Percentage</i>
O	49.20%
Si	25.67
Al	7.50
Fe	4.71
Ca	3.39
Na	2.63
K	2.40
Mg	1.93
H	.87
Ti	.58

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<i>Element</i>	<i>Symbol</i>	<i>Percentage</i>
Chlorine.....	Cl	.19
Phosphorous.....	P	.11
Total.....		99.18
All other elements.....		.82

Among those elements which make up but 0.82% of the earth, the following occur in the common minerals of the State:

<i>Element</i>	<i>Symbol</i>	<i>Element</i>	<i>Symbol</i>
Antimony.....	Sb	Mercury.....	Hg
Arsenic.....	As	Molybdenum.....	Mo
Barium.....	Ba	Nitrogen.....	N
Bismuth.....	Bi	Platinum.....	Pt
Boron.....	B	Silver.....	Ag
Copper.....	Cu	Strontium.....	Sr
Carbon.....	C	Sulphur.....	S
Fluorine.....	F	Tellurium.....	Te
Gold.....	Au	Titanium.....	Ti
Lead.....	Pb	Tungsten.....	W
Manganese.....	Mn	Zinc.....	Zn

Surprising as it may seem, most of the materials used in everyday life are comparatively rare. Usually they occur in unrecognizably small amounts in the rocks of the earth, and it is only under unusual and especially favorable circumstances that these rarer elements have been concentrated in commercial quantities. Nevada has been greatly favored as a site for the concentration of so many different substances.

In the table accompanying this bulletin the percentage composition of the commercial constituent of each mineral is given. This percentage is based on pure material, and hence gives the greatest amount of the component substance that can be present. Usually the percentages will run much lower because of the presence of other minerals as impurities. No percentages are given for a mineral useful as the mineral itself.

CLASSIFICATION OF MINERALS

Minerals may be classified in a variety of ways. The basis of classification may be use, occurrence, or some particular property, but since minerals are chemicals and since the use, occurrence, and properties of a mineral are ultimately dependent on its constitution, the best basis of classification is chemical composition. On this basis minerals may be arranged in thirteen or more groups:

1. Elements (Uncombined, free)—
Sulphur (S), Gold (Au), Silver (Ag), etc.
2. Oxides (Compounds of oxygen with other elements)—
Quartz (SiO_2), Hematite (Fe_2O_3).
3. Sulfides (Compounds of sulphur with other elements)—
Pyrite (FeS_2), Chalcopyrite (CuFeS_2).
4. Chlorides (Compounds of chlorine with other elements)—
Halite (NaCl), Cerargyrite (AgCl).
5. Fluorides (Compounds of fluorine with other elements)—
Fluorite (CaF_2).
6. Silicates (Compounds of silicon and oxygen with other elements)—
Cyanite (Al_2SiO_5), Orthoclase (KAlSi_3O_8).

es (Compounds of carbon and oxygen in the ratio 1:3 with other elements)—
 site (CaCO_3), Smithsonite (ZnCO_3).
 s (Compounds of sulphur and oxygen in the ratio 1:4 with other elements)—
 ydrite (CaSO_4), Thenardite (Na_2SO_4).
 (Compounds of nitrogen and oxygen in the ratio 1:3 with other elements)—
 r (KNO_3).
 (Compounds of boron and oxygen with other elements)—
 ax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$).
 es (Compounds of tungsten and oxygen in the ratio 1:4 with other elements)—
 bnerite (MnWO_4), Wolframite (Fe.MnWO_4).
 es (Compounds of molybdenum and oxygen in the ratio 1:4 with other elements)—
 fenite (PbMoO_4).
 es (Compounds of phosphorus and oxygen in the ratio 1:4 with other elements)—
 tite [$3\text{Ca}_3(\text{PO}_4)_2$, $\text{Ca}(\text{F}, \text{Cl})_2$].
 (Compounds containing chemically combined water—
 ax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$).

PROPERTIES OF MINERALS

As are chemical compounds they have definite physical properties and, when free to crystallize, assume definite crystal forms and plane surfaces. The chemical properties of minerals are determined by the behavior of the mineral toward other chemical reagents. A study of these properties makes possible the identification of minerals and is outside the scope of the present work.

PHYSICAL PROPERTIES OF MINERALS

Described in the description of the physical properties of minerals is the method to describe any object. The following list includes the properties commonly noted:

Color

Most minerals are colorless or white while others have a definite color. The color is determined by their chemical constitution. Very few minerals are colorless. The true color is modified by the color of impurities, inclusions, or mixtures. Surface alteration may notably change the color of a mineral as well as change its other properties. In some cases a mineral has been formed by the alteration process. Therefore, when examining a mineral a fresh unaltered surface should be used.

Luster

Depends on the kind or quality of light which a mineral sends out. Luster describes the intensity or relative amount of the light reflected. Luster thus indicates the efficiency of the mineral surface. Common terms used are: Adamantine; a very brilliant luster. Glassy or vitreous; luster of ordinary glass. Silky; the sheen of silk or satin. Other self-explanatory terms are: pearly, waxy, dull, submetallic, metallic. Only those

minerals are considered to have a metallic luster which are opaque thin slivers and which have the sheen of a metal.

Streak

The color of the fine powder of a mineral is called its streak. The powder may be easily formed by stroking the mineral across a piece of unglazed white porcelain called a streak plate. The unglazed edge of a piece of broken china or porcelain plate may be used as a substitute on which to streak the mineral. Other ways of obtaining the streak are scratching the mineral with a knife or powdering the mineral with a hammer. In the latter procedure, however, care must be taken not to contaminate the streak by material worn off the hammer.

All colorless and white minerals have white streaks. Usually the color of the streak is a tint of the mineral color but occasionally the two are quite different. When this is true the color of the streak becomes very important in the identification of the mineral. Impure minerals will give impure streaks. This fact should be kept in mind when identifying minerals.

Hardness

The hardness of a mineral is a measure of its resistance to being scratched. In no way is it a measure of its resistance to a blow from a hammer, as quite commonly supposed. Arbitrary numbers have been assigned to designate the hardness of certain common minerals so that others might be compared with them. This scale of hardness is known as Moh's Scale. In it talc is taken as the softest mineral and is said to have a hardness of 1. Diamond is the hardest known mineral and is designated 10. Eight other common minerals are arranged in order between these two. Any mineral having a hardness between two minerals in the scale is given a hardness number half way between as 2.5, 3.5, 4.5, 5.5, 6.5, 7.5, 8.5, 9.5. The numbers only show the order of hardness and in no way indicate the absolute relative hardness. Thus, gypsum is not twice as hard as talc. It is said that there is as much difference in hardness between diamond and corundum as there is between corundum and talc.

MOH'S HARDNESS SCALE

<i>Mineral</i>	<i>H.</i>
Talc	1
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

For all ordinary work it is only necessary to know that:

- A finger nail has a hardness of about 2.5.
- A copper coin has a hardness of about 3.
- Window glass has a hardness of about 5.5.
- A knife blade or file has a hardness of about 5.5.

mineral with a hardness of 1 can be scratched by all the others. One with a hardness of 4 cannot be scratched by any other. It can be scratched easily by a knife. It will easily scratch glass but will not cut a piece of glass. In determining hardness, use a smooth, unaltered surface and, in addition, be sure that the scratch is not just a trail of powder is left behind. Do not use a mineral in a scratch made by another. Granular minerals break apart in determining hardness but it is the individual grains that is to be determined. Hardness may vary with crystallographic direction. Usually hardness is not great but in the case of cyanite, for example, hardness is 4 parallel to the direction of elongation of the crystal and 2 at right angles thereto.

Specific Gravity

The specific gravity of a mineral is an expression of the weight of a mineral divided by the weight of an equal volume of water. Minerals with a specific gravity of 2.7 have about an average heft. Minerals with a specific gravity of 3.5 are noticeably heavy. Those with a specific gravity of about 2 are noticeably light, and those with a specific gravity above 3.5 are noticeably heavy. In comparing the specific gravity of two minerals, choose pieces of as near the same size and shape as possible so that equal volumes are compared.

Structure

Crystal structure, the particles arrange themselves in various ways which are usually described by familiar terms. The following are the most common:

Crystalline structure due to the orderly arrangement of atoms in the whole mass. A property not easily recognized in amorphous minerals. Most minerals are crystalline.

Amorphous crystalline, without crystal form or orderly inter-atomic arrangement.

Radial, needle-like growth of crystals.

Concentric, crystals arranged about a common center like the spokes of a wheel about the hub.

Arborescent, often minute, have produced a tree-like branching structure.

Fibrous, of thin wires or hairs.

Massive, an aggregate of fine or coarse individuals held like a lump of sugar.

Crustaceous, fine encrustation on a surface in which the surface is covered by a layer of small crystals.

Globular, a kind of structure giving a surface which resembles that of a bunch of grapes cut through the middle.

Reniform, a structure with a surface much like that of a kidney.

Foliated, leaf or book-like structure.

Schistose, a structure in which the mineral can be split into thin sheets.

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Lamellar: consisting of plates of appreciable thickness.

Stalactitic: icicle-like aggregates.

Concentric: onion-like structure composed of layers with a common center.

Concretionary: consisting of rounded particles.

Oolitic: a concretionary structure in which the rounded particles are small, like bird shot.

Pisolitic: concretionary particles about the size of a pea.

Nodular: the particles are large, rounded and irregular in shape.

Tabular: broad flat surfaces.

Compact: a uniform aggregate of minute particles.

Massive: a mineral composed of compact material and not showing any definite form is said to have a massive structure.

Disseminated: the mineral is rather uniformly distributed throughout the rock in which it occurs.

Other structural terms used in the table are self-explanatory.

Form

When a mineral is free to crystallize while it is forming it usually assumes some definite shape called a crystal. Such shapes are:

Cube: six square faces at right angles to one another.

Rhombohedral: an equal six-sided form in which the sides have parallel but not right-angled edges. Such a form as is produced when a cube is distorted by pushing at one of the corners.

Prism: faces usually rectangular, with parallel edges.

Pyramid: a crystal form with triangular faces which meet in a point; a peak-like form.

Octahedron: an eight-sided figure with equal triangular faces.

Tetrahedron: a four-sided form with equal triangular faces.

Dodecahedron: a twelve-sided figure bounded by diamond-shaped faces or by five-sided faces as in the case of the *pyritohedron*.

It is only under very favorable circumstances that a mineral will form good, easily recognizable crystals. Those inexperienced in mineral determination will find this property of little use.

Cleavage

Some minerals tend to break along smooth, flat surfaces. This property is called cleavage. The planes so produced glisten in the light and even though the mineral may be an aggregate, each grain will show its cleavage faces by the light it reflects to the observer's eye. Cleavage is described according to the cleavage form produced. For example, a mineral with cubic cleavage, like galena, can be broken into small cubes. Usually it is only necessary to determine the number of different plane surfaces produced when the mineral is broken and to note the perfection of the surface and the ease with which it may be obtained. Some minerals, like galena, break equally well in three directions; others, like mica, are only cleavable parallel to one direction.

Fracture

A surface which is not a flat cleavage surface is called a fracture. Minerals which have poor cleavage yield good fracture. Fracture is always determined in a direction in which the mineral is broken. The kinds of fracture are:

- 1. Conchoidal fracture, but not flat surface.
- 2. Subconchoidal fracture, a surface without any special character.
- 3. Irregular sharp edges in the broken surface.
- 4. Shell-like surface with curved and often concentrically marked markings.
- 5. Mud-like fracture.
- 6. Surface like that of clay or chalk.

Tenacity

The tenacity of a mineral is that property which depends upon the strength of the particles, or the power they have to hold together. It is used to describe this property:

- 1. Brittle, shattered by a hammer blow.
- 2. Malleable, can be hammered into thin sheets.
- 3. Ductile, drawn out into a wire.
- 4. Fragile, some minerals which can be crushed or worn off in the form of thin shavings by a knife.
- 5. Flexible, sheets of the mineral can be bent back and forth without breaking.
- 6. Elastic, sheets of the mineral can be bent within the so-called elastic limit but will not remain bent after the distorting force is removed.
- 7. Tough, resisting shattering by hammer blows. Opposite to brittle.

Diaphaneity

Transparency depends on the ability of the mineral to allow light to pass through it.

- 1. Transparent, a mineral is one through which printing can be seen.
- 2. Translucent, a mineral allows light to come through but this is too faint to give clear vision through the mineral.
- 3. Opaque, a mineral will not transmit light even when thin. Thin sections of a mineral will not allow light to come through their surfaces.

Special Properties

Minerals have other characteristics in addition to those already mentioned. Under this heading are included solubility in water, taste, and magnetism. Only soluble minerals have a definite taste. Minerals should be tasted by breaking off a small fragment, tasting it, and then moving it from the mouth. Odor is best obtained if the mineral is first moistened by blowing the breath upon it before testing. Some minerals like the metals and hard rock minerals, are hard, harsh, greasy, or soapy when rubbed between the fingers. Magnetism can be tested best by suspending a horseshoe magnet over the mineral, noting the presence or absence of attraction when the mineral is brought near the magnet.

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mineral is brought up to the magnet. A few minerals show a play of colors called iridescence when turned in the light. Such phenomenon is seen when oil is dropped on water. When a mineral is doubly refracting, printing will be blurred or seen double when viewed through it. This only can be tried on transparent minerals. A striated mineral will show fine parallel lines or scratches on its surface.

Minerals illustrating the foregoing properties may be found by referring to the accompanying table.

MINERAL ASSOCIATIONS

Most minerals are stable only under certain conditions and when they are removed from this environment they undergo change. Therefore, minerals are indicators of the formation in which they occur. Some are stable when deeply buried, others are stable at the surface. Some occur in hard crystalline rocks, others only in surface deposits. Those minerals are found together which are produced by the same kind of processes or which are alike chemically. For example, galena, sphalerite, or pyrite and chalcopyrite are often found together because they are all sulphides and are produced in the same kind of way. Similarly, in the upper part of veins carbonates like malachite, azurite and cerussite are found with such oxides as limonite, cuprite, and hematite. This is due to the fact that some of the original minerals have been altered by the carbon dioxide of the air while others have been affected more directly by the oxygen therein. The fact that minerals are often accompanied by their alteration products is a real aid in mineral identification. For example, chalcopyrite becomes coated by green malachite whereas pyrite which may be mistaken for chalcopyrite alters to brown limonite.

Minerals are not haphazardly distributed in the rocks but occur where they do because certain forces have acted. Hence they often indicate the forces which have produced them. They may indicate the nature of an ore deposit, may sometimes give information regarding the feasibility of sinking a shaft deeper, or of abandoning all hope and saving the expense. The one who best understands minerals will best be able to interpret the forces which have produced them.

THE DETERMINATION OF MINERALS

Minerals may be identified on the basis of their characteristic properties. When all other methods fail it is usually possible to determine a mineral by a complete chemical analysis but, since this is expensive and involves much labor and skill, it is usually employed only as a last resort. Fortunately, most of the common minerals have distinguishing physical properties by which they can readily be identified. Such a determination may then be checked, if necessary, by chemical tests for the substances the mineral contains.

In the accompanying table the minerals are arranged systematically according to their physical properties. Streak is the first property to be determined when this table is used. This is easily obtained by one of the methods already described. The streaks are arranged from the pale colors to the dark ones and minerals having the same colored streak are listed in order of increasing hardness. When more than one mineral has been included for a given hardness the list is in the order

gravity. These three properties in general will to a few minerals which can then be discriminated by their properties. Occasionally the mineral association is rare and should not be overlooked. In no case should identification be based on just one or two tests and in every case should be determined without preconceived ideas as to what the mineral may be. If the owner wishes confirmatory chemical tests, textbooks on mineralogy or blowpipe analysis may be consulted. A list of minerals is published by the Mackay School of Mines on request. This list includes only the more common minerals of the State and the names of these are printed in capital letters. When there is doubt as to the identity of a mineral it is best to call it the name of the mineral it most closely resembles. The chance of being right is greater than any other.

A Mineralogical Laboratory is maintained at the Mackay School of Mines for the exploitation of the minerals of the State. Within the law, it will mail a mineral and assay report to any person who submits for analysis samples obtained within the State. Those who use this privilege will find this bulletin useful in identifying a sample which has been analyzed by the State Laboratory. Since the Laboratory does not return samples, it is convenient to keep duplicate samples to compare and the report when it is received.

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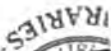
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UNIVERSITY OF NEVADA BULLETIN

MARCH 15, 1928

No. 2

A BULLETIN

BY

WILLIAM H. KAY SCHOOL OF MINES STAFF

ON THE MINERAL

MORTIERITE



PUBLISHED QUARTERLY BY THE UNIVERSITY OF NEVADA
RENO, NEVADA

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MARCH 15, 1928

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A BULLETIN

BY

WILLIAM H. CROOK
MCKAY SCHOOL OF MINES STAFF

ON THE MINERAL

UMORTIERITE



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FOREWORD

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MINERALOGY OF DUMORTIERITE

By O. R. CRAWFORD

Lecturer in Mineralogy, Mackay School of Mines

HISTORY AND OCCURRENCE

Dumortierite as a distinct mineral species dates back to 1879, when Ferdinand Gonnard (16)¹ checking up on the petrologic and petrographic observations of A. Drian in Lyon, France, chanced to see a beautiful fibrous blue mineral in the feldspar of one of the gneissic blocks among a group of stones used in repairing the road near Beaunant. At the time he thought the mineral might be cyanite and made no attempt to separate it or to trace it to its source. Later he submitted a small amount of material to Bertrand for determination. The microscopic and other optical properties convinced Bertrand that it was unlike any known and in his note of 1880 (1) he named it a new species. This is the first published article on dumortierite. With the encouragement of having found something new, Gonnard returned to the original locality and collected material. He returned the basis of his paper of 1881 in which he named dumortierite in honor of the Lyon palaeontologist, Eugène Dumortier. Gonnard's article was accompanied by Damour's (6) analysis and formula for the new mineral.

Since its discovery, dumortierite has followed the discovery of dumortierite, the mineral has been observed in many localities of world-wide distribution. It occurs in minor amounts as acicular, often radiating or fibrous crystals in minerals contained in pegmatite or quartz veins in aluminous rocks and it occasionally occurs in separate veins in larger quantities. At Beaunant, southwest of Lyon, France, Gonnard found it in a pegmatite which cuts cordierite gneiss. Similar occurrences near Oullins (17) and along the Rhine near Brignais (18). Websky (49) was the first to find dumortierite outside of France. He found it in pegmatite in the Riesengebirge of German Silesia, at Wolfshau, near Liegnitz. Similar occurrences have been observed in the Riesengebirge (19) and in Switzerland. From the southern part of the Argovian massif of the Swiss Alps, Hugi and Hirchmann (20) described an occurrence of dumortierite in a quartz, rich in dumortierite, and Linck (30), much earlier, described a similar occurrence in the pegmatite of the lower Val Donbastone in Upper Bavaria. Southern European occurrences are located in Czechoslovakia (40) has observed dumortierite in the kaolinized granite of a muscovite biotite granite at several places in the Bohemian Massif, at Imligau near Chodeau, at Schobrowitz, near Karlsbrunn, near Pilsen. Kratochvíl (24) records another occurrence at Pelhřimov, near Putimov, where the dumortierite occurs in a dike traversing granite and gneiss and in which the dumortierite is accompanied by andalusite. The green fibers and prismatic aggregates of dumortierite are referred to the numbered articles in the bibliography.

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accompany sillimanite in small pegmatite veinlets which traverse sillimanite biotite gneiss at Vymyslice, near Moravský, Krumlov (39).

Northern as well as southern Europe contains minor amounts of dumortierite. It is a microscopic constituent of a pegmatite which cuts garnet mica gneiss and such basic rocks as peridotite, pyroxenite gabbro, and others on the Kyshtymk estate in the Uvildy Lake district of the Russian Urals (25). Inclusions of dumortierite in the cordierite gneiss of southern Norway have been described by Michaëlsen (26). Lévy and Lacroix (32, 26) from the vicinity of Bamle, Tvedestrand, Kragerö, and Arendal. Mackie (33) recently has recorded the occurrence of the mineral in the gneiss, granite, and pegmatite of four localities in Aberdeenshire and Banffshire, Scotland, and in the granite of Cornwall, England.

Anfoka, near Soavina, 25 kilometers north of Ambalofinandrahan, Madagascar, is the only African locality in which dumortierite is known to occur. According to Lacroix (27), the mineral is disseminated in a quartzite which is accompanied by other quartzites containing lazulite. In view of all other occurrences, one wonders if Lacroix's quartzite may not be veins of granular replacement quartz.

In the South American Continent dumortierite has been found in Argentina and in Brazil. It occurs as an accessory mineral in granite at Potrero, Province of Catamarca, Argentina (38), and as fibrous aggregates in pegmatites at Rio de Janeiro (12, 37). Riman (37) records two occurrences of dumortierite near Rio de Janeiro, one in the suburb of Copacabana where two pegmatite dikes intrude a garnet cordierite gneiss; the other at Ipanema in the south slope of the Morro de Cantagallo where six pegmatite dikes, four of which contain dumortierite, cut cordierite sillimanite gneiss. Ferraz and Roccati (12) more recently have recorded the occurrence of dumortierite in the diamond-bearing sands at Diamantina, Riacho de Varras, Candonga, and Cachorra de Paraima.

North American dumortierite has been found in one locality in Canada, one in Mexico, and in several in the United States. In 1925 brief mention was made of the presence of dumortierite in the NW 1/4 Lot 31, 14th Concession of Ashby Township, near Bancroft, Ontario, where a pegmatite vein one foot wide intersects a gneiss (53). In a later paper Walker (48) described this occurrence more fully. The dumortierite is included in muscovite, quartz, and microcline and coats joints in the pegmatite itself. The Mexican dumortierite of the Sierra de Guadalcázar in the State of San Luis Potosí forms the basis of the papers by Wittich and Kratzert (51, 52). It is associated with topaz in quartz boulders which the authors believe to be derived from pegmatite veins cutting the granite laccolith at Realejo, four kilometers northwest of Guadalcázar, because the streams carrying the boulders have their source in this granite mass. The presence of dumortierite with such fluorine minerals as topaz and fluorite makes this occurrence very much like those in Brazil.

Seven of the United States contain dumortierite: Arizona, California, Colorado, Nevada, New Mexico, New York, and Washington. The intense blue color of the mineral at Harlem, New York, attracted the attention of mineral collectors early in the Nineteenth Century, but, lacking petrographic microscopes, they classified it as the blue

aline, indicolite. It is so recorded in Webster's (50) minerals of New York State, published in 1824, and until 1887 when Riggs (36) had occasion to examine a indicolite. His analysis showed that although the mineral boron, its composition was quite different from that of a subsequent hasty examination by Diller also showed it was not tourmaline but it was left for E. S. Dana (7) to determine the mineral might be identical with Gonnard's dumortierite analyses by Whitfield (9, 10) and further examinations with the French material by Diller (9, 10) to confirm Dana's suggestion. The New York mineral specimens, needles and fibrous radiating tufts, included prismatic, and sparingly scattered through a pegmatitic gneiss. Chamberlain (4) wrote that as early as 1856 by S. C. H. Bailey at Kip's Bay, near the upper Manhattan Park, many other localities within New York City, previously listed by Chamberlain (4) and Hovey (20), and Diller (44).

Specimens from Clip, Arizona, were described and named by Ford and Whitfield (9, 10) in 1889. Later, material from Clip was analyzed by Ford (14, 15) and further studied by Ford (45), who described the mineral as occurring only in a quartz rock associated with cyanite, magnetite, and hematite and has passed out of existence. It is not to be found on the Colorado River and no longer is it listed in the Postal Guide. Regarding its location has been supplied by Dr. W. F. Ford states that old atlases show the location of Clip to have been on the Colorado River, near the present camp of Cibola. The place is now referred to as Clipper Gap. He continues: "This is the landmark called Picacho Peak and the two dumortierite localities are probably identical. Rolled boulders are sent us from Ogilby and specimens of cyanite that are associated with the dumortierite are in our collection. The American Girl Mine about 10 miles north of Ogilby, three miles north of Ogilby. There is perhaps a belt of cyanite rocks in this district." Specimens in the collection also show a striking similarity between the Clip specimens and that from Imperial County, California, in the vicinity of Warner's. It is likely that the boulders at Clip actually had come from California.

Dean G. M. Butler,¹ dumortierite occurs in two other localities in the State of Arizona. One is the Patagonia Mining District, northeast of Nogales, the other is in the northern part of the Pinal County south of Quartzite.

For a more complete explanation of the source of the Clip dumortierite, the mineral was first mentioned by Ford (14, 15) as occurring in a dike, 30-40 feet wide which cuts a biotite-granite at Dehesa, San Diego County, California. According to Ford the upper part of this dike is a fine-grained, whitish, or light gray quartz containing sillimanite, a little muscovite, and

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no dumortierite. Downward the dike loses its schistosity, becomes coarser and dumortierite appears. Both dumortierite and muscovite become more abundant with depth.

The University of California recently supplied us with a specimen of dumortierite obtained by Charles Anderson four miles northeast of Corona in Riverside County, and other California occurrences in Imperial County have been called to our attention by Dr. Jeffery and by Dean Butler,¹ who sent us a specimen obtained six miles northwest of Picacho Peak, but no geologic reports have been published concerning these deposits.

The only account of dumortierite in Colorado is that published by Findlay (13) in 1907. He found the mineral associated with corundum and sillimanite along Grape Creek, seven miles southwest of Canyon City, Fremont County, Colorado. The parent rock is a pegmatite dike 40-80 feet wide which cuts through an epidote schist.

At the headwaters of the North Fork of the Washougal River in Skamania County, Washington, small spherulites of fibrous dumortierite occur in a fine-grained mass of muscovite, andalusite, and quartz. Specimens from this locality were first described by Ford (14, 15) and later by Schaller (44). A similar occurrence of dumortierite in New Mexico has been noted by Schaller (45). A quartzose sericite rock in the Tres Hermanas mountains of Luna County, 12 miles northwest of Columbus, contains blue spherulites of dumortierite.

Dumortierite is known to occur at four places in Nevada. Jones (22) observed the pink variety in the sericite schists of the Rochester Mining District of Pershing County, but in his hasty examination mistook it for rubellite. Knopf (23) later called attention to this mistake and published the first account of dumortierite in the State. He described the dumortierite veinlets in the Triassic (Koipato) sericite schist on the west slope of Lincoln Hill in the Rochester District. This work was published in 1924. In the next year R. H. Rowland discovered that his claims in Pershing County, in the Humboldt mountains just north of the Rochester District, contained a large deposit of dumortierite. This deposit lies in Humboldt Queen Canyon (sometimes referred to as Limerick Canyon, which is really to the south) six miles east of Oreana. Rowland's claims were purchased by the Champion Porcelain Company of Detroit, Michigan (subsidiary of the Champion Spark Plug Company of Toledo, Ohio), in October, 1925, and development work was begun. The highest grade dumortierite has been shipped to the Porcelain Company's plant at Detroit, Michigan, and used in the manufacture of spark plug porcelain, thus making the Humboldt Queen deposit the only commercial occurrence of dumortierite in the world. Fairbanks (11) and Peck (35) have already described the mineralogical properties of this dumortierite and, since it is the primary purpose of this bulletin to discuss this deposit quite fully, there is no need of further discussion here.

Another known locality of dumortierite in Nevada is at the southern end of the Granite Range in Washoe County, approximately eight miles northwest of Gerlach. R. M. Oliver, who has recently visited the locality, describes the pink dumortierite as occurring in segregations in the granite associated with quartz and muscovite. The fourth locality,

¹Personal communications to Director Fulton.

ound Mountain in Nye County. The mineral is a blue and, according to H. S. Clinton,¹ it occurs in a granite within a granite mass. Neither of the latter has been investigated and much work remains to be done.

MINERALOGICAL PROPERTIES

A. Crystallographic Properties

Crystals of dumortierite have been found. Practically all forms of the mineral have been determined by Schaller based on six incomplete prismatic specimens: two from Arizona, one from Clip, Arizona, and three from New Mexico. Dumortierite is orthorhombic with the following axial ratios: $a:b:c = 1:0.6871$.

Forms described by Schaller are:

- a. macro pinacoid (100)
- b. brachy pinacoid (010)
- m. Unit prism (110)
- l. brachy prism (120)
- g. macro prism (320)
- n. macro prism (210)
- d. macro dome (102)
- v. macro dome (203)

Several other forms but the faces were too minute for certainty. Dumortierite crystals are often vertically twinned faces due to repeated pseudo-hexagonal twinning laws obeyed by cordierite and aragonite (44, 48). Crystallographic data may be obtained from Schaller's

B. Physical Properties

Frequently some kind of blue variously described as amethystine, lilac, or sodalite-blue. Weathered surfaces are often nearly black. Notable exceptions to the rule are: the pistacite green dumortierite of the Valais and of Brazil (37), the lavender of Riverside County, California (44) and Nevada (11, 23, 35), the pink of Arizona (11, 23, 35), and Madagascar (27). When heated above 800° C the mineral becomes permanently gray-

The color of dumortierite has been subject to some speculation. (36) suggested that the color might be due to titanium. He tried to get a titanium test by the hydrogen peroxide method. The Washington dumortierite free from rutile and the California lavender dumortierite contains about 0.1% Ti. From this it would seem that the blue dumortierite contains replacing aluminum, whereas the red does. Lacroix agrees with this, finding titanium in both the rose and the pink of Madagascar, but one does not know whether the test have the test occurred as rutile or titanite, or as a part of the aluminum. Peck (35) found practically no difference in the refractive indices of pink dumortierite and of light blue crystals and thus ruled out Fairbanks's theory. (Personal communication.)

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(11) suggestion that there might be some relationship between titanium content, color, and refractive index. As pointed out by Peck, the dumortierite usually contains inclusions of rutile which indicate that the dumortierite has absorbed its full amount of titanium, and hence probably forms a part of the molecule of both the pink and blue varieties. This conclusion is further borne out by the fact that Peck has discovered some veinlets of dumortierite which are blue near the walls and pink at the center. Jones has found a similar gradation in the Nevada dumortierite while Walker (48) observed that the centers of some dumortierite crystals have a different pleochroism from the exteriors. Peck suggested that perhaps the color may be due to the state of oxidation of the titanium. In blue dumortierite it may be present as Ti_2O_3 and replace a part of the alumina, in pink dumortierite it may be oxidized to TiO_2 and replace a part of the silica. As further pointed out by Peck, however, the color effects of iron, manganese, and other small quantities of other elements must not be overlooked, and one must keep in mind that "the color of the mineral is a matter easier to speculate upon than to prove."

Streak. A light tint of the color, nearly white.

Luster. Vitreous to mat (dull).

Diaphaneity. Transparent to translucent on thin edges or in crystals, but massive material appears to be opaque.

Structure. Fan-shaped radiating masses, fibrous, acicular, prismatic crystals, occurring in masses, in spherulitic aggregates and as inclusions.

Cleavage. Distinct parallel to macropinacoid (100). Indistinct parallel to prism (110). Indistinct parallel to brachy pinacoid (010).

Cleavage Angles—

$$110 \wedge 110 = 124^\circ \pm (9, 10). \quad 100 \wedge 110 = 152^\circ \pm (9, 10)$$

Fracture. At right angles to the c axis.

Parting. Imperfect parallel to basal pinacoid.

Hardness. 7.

Tenacity. Very tough in massive aggregates.

Specific Gravity. Maximum is 3.36. Average 3.30. Variations in recorded specific gravities are largely due to variations in purity of material.

Fusion Point. On being heated, dumortierite decomposes to mullite which fuses at $1810^\circ C(3)$.

Dielectric Constants. Fairbanks (11) has determined the dielectric constants of Nevada dumortierite and two other aluminum silicates:

Dumortierite (violet) Nevada.....	17
Dumortierite (red) Nevada.....	17
Andalusite (bluish) California.....	8
Andalusite (bluish) Tyrol.....	12
Cyanite (blue) Nevada.....	7-9

X - infinite. Error ± 1

C. Optical Properties

Figure, Biaxial.

Negative.

Section—

Ref.	Locality	α	β	γ
11	Nevada	1.677 _{Li}		
29	California	1.670 _{Na}	1.691 _{Na}	1.692 _{Na}
31	Norway	1.650	1.712	1.728
30	Switzerland	1.678 _{Na}	1.686 _{Na}	1.689 _{Na}
35	Nevada (pink)	1.677 _{Na}	1.685 _{Na}	1.690 _{Na}
35	Nevada (lavender)	1.675 _{Na}	1.685 _{Na}	1.690 _{Na}
35	Nevada (light blue)	1.675 _{Na}	1.685 _{Na}	1.692 _{Na}
48	Canada	1.659 _{Na}	1.684 _{Na}	1.686 _{Na}

Error = $\pm$ 0.003 $(\gamma - \alpha) = 0.010$ to 0.027 .Strong but indeterminate. $\rho > v$ (25, 26, 32, 35)7, 29, 44). Lacroix gives both $\rho > v$ (26, 32) andview of Schaller's (44) work $\rho < v$ seems to be correct.

The axial angle (2E).

California (44) ----- 33°_{Li} , 37°_{Na} , 42°_{Cu} .Canada (48) ----- $95^\circ \pm$.Mexico (51, 52) ----- $50^\circ \pm$.

Wildy Lake (25) ----- Small.

Axial angle (2V).

Canada (48) ----- $52^\circ \pm$.France (44) ----- 35°_{Na} to 40°_{Na} .Madagascar (27) ----- $35^\circ 40'_{Na}$.Nevada (35) ----- 30° – 40° .Norway (26, 32) ----- $35^\circ \pm_{Na}$.

Switzerland (30) ----- Less than that of muscovite.

Strong.

Ref.	α	β	γ
40	Deep blue	Colorless	Colorless
	Reddish brown		
	Olive green		
	Deep carmine		
	Light olive green		
37	Light to dark blue	Colorless	Colorless
	Violet		
	Dark wine red		
	Bluish green		
	Greenish yellow		
	Dark green		
	Greenish brown		

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Locality	Ref.	α	β	γ
California	44	Reddish purple	Colorless	Colorless
Canada	48	{ Berlin blue Some crystals show green interiors }	Colorless	Colorless
France (Brignais)	44	Rose-salmon	Colorless	Colorless
Mexico	51, 52	Blue	Lilac red	Colorless
Moravia	39	Dark blue	Yellowish	Colorless
Nevada	11, 35	Blue, reddish, violet, lavender	Colorless	Colorless
Switzerland	30	Pistachio green	Colorless	Colorless
Other localities	1, 19, 26, 27, 32	{ Cobalt blue Light blue }	{ Straw color Pale yellow Colorless }	Colorless

Orientation. $Z \parallel a$, $X \parallel c$, $Y \parallel b$.

Acute bisectrix is perpendicular to c axis.

Elongation. Parallel to c .

Inclusions. Diller (9, 10) observed liquid inclusions and long tubular cavities in dumortierite. Rutile and titanite inclusions are also common.

Pleochroic Haloes. Observed by Lacroix about inclusions of dumortierite in the cordierite of Norway.

D. Chemical Properties

Infusible before the blowpipe.

Loses color on strong ignition.

Yields a blue color when heated with cobalt nitrate on charcoal before the blowpipe.

Renders a salt of phosphorous bead slightly bluish and opaline.

Insoluble in acid including cold hydrofluoric acid. Quite resistant to weathering and hence found among detrital products.

Many specimens when fused with sodium carbonate will give a test for titanium with hydrogen peroxide.

When intimately mixed with potassium bisulphate and calcium fluoride and introduced into a colorless flame, the green flame of boron may be obtained, but this is a very delicate test and may fail.

The behavior of dumortierite on heating at high temperatures was investigated by Bowen and Wyckoff (3) who found that the mineral quickly turns white at 800°C and slightly turbid at 950° . The refractive index is slightly lowered and after 10 minutes heating at 1200° the average index becomes 1.61, the elongation becomes positive and the product shows characteristic X-ray spectrum lines of mullite [Vernadsky (47) had stated earlier that the decomposition product is sillimanite]. After two hours heating at 1400° , dumortierite completely breaks down to mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) and probably silica and boric oxide. Boric oxide and water are completely expelled in 4 hours at 1500° at which temperature sintering begins. Liquid first appears at 1550° due to the melting of the eutectic between mullite and silica (1545°). For all practical purposes dumortierite at high temperatures behaves like a material containing only alumina and silica, nearly if not actually, in the proportion $4\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$, the formula which Damour originally assigned to the mineral.

ASSOCIATIONS OF DUMORTIERITE

commonly occurs as fibrous acicular, and fan-shaped minerals, chiefly in quartz, muscovite, feldspar, and occasionally, as in Humboldt Queen Canyon, Pershing County, it occurs in large masses, but even here much of it is quartz and muscovite.

Minerals associated with dumortierite are indicated in the table. Usually some other aluminum mineral is present, e. g., corundum, cyanite, pyrophyllite, sillimanite, or some boron associate is tourmaline. While feldspar and dumortierite in many localities, it is notably absent in Madagascar, Mexico, Arizona, California, Nevada, New Hampshire, and Washington. In some localities biotite and cordierite are constituents of the country rock. Quartz, however, is not an associate, and muscovite is usually present either as a primary mineral or as an alteration product. In some places dumortierite is altered to muscovite (sericite, or damourite). For example, in the Washington and New Mexico deposits have been observed (Schaller (44, 45) to be altered entirely into muscovite. An investigator has also observed pseudomorphs of dumortierite in the French material (44). Sulphides are commonly found accompanying dumortierite, but pyrite does not occur in these localities. Other minerals found with dumortierite are in very small amounts as inclusions or as alteration products (see table on pp. 16 and 17.)

Minerals which have been found with dumortierite but which are not in the table are:

Madagascar: beryl, graphite, monazite, pinite.

Madagascar: monazite, pinite, spinel.

Madagascar: chlorophyllite and fahlunite as alteration products of dumortierite.

Madagascar: chlorite.

Madagascar: lazulite.

Madagascar: axinite, fluorite, hematite.

Madagascar: spinel and wernerite as inclusions in cordierite, and esmarkite, polychroite, and prasecolite as alteration products of cordierite.

Madagascar: chrysoberyl and chlorite as an alteration product of biotite.

New York City: xenotime and monazite as inclusions in quartz, monazite in orthoclase, torbernite (?), and xenotime (?).

Granite Range: leucosene.

Humboldt Queen Canyon: chlorite, leucosene.

Pershing County, Skamania County: leucosene.

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THE MINERAL DUMORTIERITE

Locality	Reference Number	MINERAL ASSOCIATION	
		Dike Rock	Country
Argentina, Portrero, Catamarca	38	Aplite	Granite
Bohemia, Pelrimov	24	Pegmatite	Granite
Brazil, Copacabana	37	Pegmatite	Cordierite
Ivanema	48, 53	Pegmatite	Cordierite
Canada, Ashby Township	16, 17, 18	Pegmatite	Gneiss
France, Department of Rhone	49	Pegmatite	Cordierite
Germany, Wolfshau	27	Pegmatite	Quartzite
Madagascar, Anfoka	51, 52	Pegmatite	Granite
Mexico, Guadalcázar	39	Pegmatite	Granite
Moravia, Vymyslice	26, 32	Pegmatite	Cordierite
Norway, Tvedestrand, etc.	25	Pegmatite	Basic igneous rock and granite
Russia, Uvildy Lake	30	Pegmatite	Granite
Switzerland, Veltlin	21	Pegmatite	Granite
Bergeller Massif	9, 10, 14, 15, 42, 43, 44	Quartz	
UNITED STATES:	a	Quartz	
Arizona, Clif, Yuma County	a	Quartz	
Patagonia Mining District	b	Quartz	
California, 6 mi. NW. Picacho Peak	14, 15, 42, 43, 44	Quartz	
Imperial County	13	Quartz	
Riverside County	a	Pegmatite	Biotite granite
San Diego County	11, 35, a	Quartz	Epidote schist
Colorado, Canyon City	23	Quartz	Granite
Nevada, Granite Range	a	Quartz	Sericite schist
Humboldt Queen Canyon	45	Quartz	Sericite schist
Lincoln Hill	14, 15, 42, 43, 44	Pegmatite	Granite
Round Mountain		Quartz	Mica schist
New Mexico, Luna County			Biotite granite
New York, New York City			
Washington, Skamania County			

- a Work of Jones in this bulletin.
 b Determination by Dr. Peck and communicated by Dr. Jeffery.
 Ad Alteration product of dumortierite.
 Id Inclusions in dumortierite.

CHEMICAL ANALYSES

Fifteen chemical analyses of dumortierite from ten different localities have been published by ten analysts. The following compilation of these analyses shows that no two of the ten analysts quite agree on the composition of the mineral. The causes of disagreement are: (1) small amount of material available for analysis, (2) difficulty of obtaining material of requisite purity, (3) difficulties inherent in methods of analysis, (4) failure on the part of some analysts to detect all constituents present, (5) the probability of vicarious replacement of aluminum by boron, hydrogen, iron and titanium.

Dumortierite of all localities is so intimately associated with other minerals that material of sufficient purity for chemical analysis can be obtained only by employing special means of separation. Even then the material obtained may contain inclusions and therefore should be microscopically examined before it is analyzed. Often the amount of pure mineral obtainable is so small that considerable error is introduced in the analysis of the lesser constituent. Damour (6), in making the first analysis of dumortierite, introduced a method of purification which has since been used with modification by other analysts. Making use of the fact that dumortierite is not attacked by cold hydrofluoric acid while quartz and feldspar are, he treated his material with a mixture of hydrofluoric and sulfuric acids and obtained relatively pure dumortierite. This he further purified by drying, grinding and stirring in Thoulet's solution (potassium mercuric iodide). The dumortierite which sank in the solution was used for analysis. Ford (14, 15) reversed Damour's procedure. He crushed the mineral and first separated it from the lighter minerals by using Thoulet's solution and then barium mercuric iodide. Ford hand-picked the heavy concentrate and digested the selected material in cold hydrofluoric acid. Whitfield (9, 10) first used Klein's solution (cadmium borotungstate) and an electromagnet to get out the tourmaline but found the employment of Thoulet's solution and the digestion with hydrofluoric acid to be a better procedure. Schaller (42, 43, 44) used only heavy liquid separation but made a careful microscopic examination of the material to be analyzed. Todd (48) used Braun's solution (methylene iodide) as the separating medium.

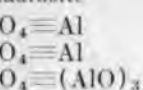
According to Schaller (44), "an analysis of dumortierite is a difficult operation." He found (a) that the mineral must be fused with soda at least twice, (b) that the handling of large quantities of gelatinous aluminum hydroxide (plus those of iron and titanium) is cumbersome, (c) that a triple precipitation of the aluminum hydroxide is necessary, (d) that the Gooch method for the determination of boron is the best, providing all the known precautions are taken, (e) that the determination of water by ignition loss is not satisfactory.

Damour originally assigned the formula $4\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$ to dumortierite as a result of his analysis of Gonnard's material. He did not suspect the presence of boron. Subsequent spectroscopic analysis of a few hundredths of a gram of the French material indicated to Raoul* (28) that the boron content of this material was much less than that obtained in American localities, but Ford (14, 15) had already pointed out that boron is not easily detected by qualitative tests. The difficulties involved in boron determinations are indicated by the wide range

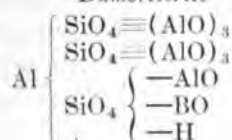
tierite from a single locality, Harlem, New York. Only a trace of boron; Riggs found 4.07%, but his is entirely free of tourmaline, while Ford found 6.14%. The results in the determination of the water content are not in agreement with Schaller's analyses of the Clip dumortierite. Only six indicate the presence of titanium, a few indicate the presence of iron, while other analyses indicating high iron, magnesium, sodium, and potash show that the mineral was not pure.

It is interesting that titanium and iron may replace aluminum, but that "it has not been proved that either boric acid or silicic acid and hydroxyl may mutually replace each other as fluorine and hydroxyl are known to do. There is, therefore, at the writer can see why the alumina, boric acid, and dumortierite should not be present in fixed quantities and the results shown in analyses are not due to isomorphous substitution or inaccuracy of analyses or impure material." Ford does not agree with this, but at the present time the analyses of dumortierite which are considered best are Schaller's (48), $8\text{Al}_2\text{O}_3 \cdot \text{B}_2\text{O}_3 \cdot 7\text{SiO}_2 \cdot \text{H}_2\text{O}$, and Todd's (48), $8\text{Al}_2\text{O}_3 \cdot \text{B}_2\text{O}_3 \cdot 7\text{SiO}_2 \cdot \text{H}_2\text{O}$. Only one molecule of SiO_2 . Structurally Schaller has shown that dumortierite is similar to that of andalusite:

Andalusite



Dumortierite



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tnO	ig. I	Proposed formula
0.11	pure	$\frac{1}{2}O_2 \cdot B_2O_3 \cdot 7SiO_2 \cdot H_2O$
		$\frac{1}{2}O_2 \cdot 3SiO_2$
		$\frac{1}{2}B_2O_3 \cdot Si_2O_3$
	pure	
		$O)_{18}(Al,B)_4(SiO_4)_7$
		$\frac{1}{2}Si_2O_3 \cdot AlB_2O_3 \cdot 2H_2O$
	pure	
		$O)_{18}(Al,B)_4(SiO_4)_7$
		$\frac{1}{2}O_2 \cdot B_2O_3 \cdot H_2O \cdot 6SiO_2$
Loss free		
	ure material	
		$\frac{1}{2}K)_2O \cdot 10Al_2O_3 \cdot B_2O_3 \cdot 10(SiO_2) \cdot 3H_2O$
	ure	

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GY OF THE DEPOSIT OF DUMORTIERITE IN HUMBOLDT QUEEN CANYON, WASHINGTON COUNTY, NEVADA

GENERAL GEOLOGY

By J C. JONES

Geology and Mineralogy, Mackay School of Mines

Dumortierite is a rare mineral, yet it has been found practically everywhere associated with granites, pegmatite dikes, high grade veins, and contact metamorphic deposits. With the addition of dumortierite makes an unusually valuable porcelain the search for suitable deposits has been essential, aside from a sufficient quantity and a deposit be practically free from quartz and other minerals, though such minerals as andalusite and muscovite in considerable amounts.

One suitable deposit has been found, the deposit on the Humboldt Range near Oreana, Nevada, owned and operated by the Champion Porcelain Company, of Detroit, Michigan. The problems suggested in a study of this deposit are of the mode of occurrence and origin that determines the dumortierite of this locality in contrast to the other known occurrences of the desired mineral.

The results of the present study, it may be stated that the deposit from this locality is won from lenticular masses formed by solutions originating in a granitic magma region. While dumortierite also occurs in quartz veins in known localities, yet the lenticular masses originated from the cement of pre-existing lenses of andalusite formed in the stage in the metamorphism of the rocks by the replacement. During the period of replacement of the andalusite by dumortierite, the quartz-dumortierite veins forming later. The deposit contains only the tolerated minerals and can be utilized, and is worthless.

The deposit owned by the Champion Porcelain Company is located on the Humboldt Range, Nevada, a station on the transcontinental Southern Pacific railroad. The area is just beyond the boundary of the geologic map (23, plate 1)¹ of the Rochester District, three and a half miles northwest of Lower Rochester. The deposit is near the head of a small canyon locally known as Limerick Canyon located between Limerick Canyon to the south and Limerick Canyon to the north. On the map of the Forney² Limerick Canyon is designated as Sacramento Canyon. The present large canyon two miles north is known as Limerick Canyon.

The Humboldt Range has been well summarized by the description of the geology of the Rochester District.

For further information refer to the articles listed in the Bibliography.
Geol. Surv. 40th Par. Atlas, Map V, east half.

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The Humboldt Range is largely composed of a thick series of volcanic tuffs and breccias in part interbedded with sediments, limestones, shales, and sandstones of middle and upper Triassic. As the igneous rocks largely lie below the sediments the Forti-
 alle Survey¹ separated the Triassic rocks into two groups, naming the lavas the Koipato, the sediments the Star Peak Formation. During the close of the Mesozoic Era these were intruded by granites and
 In the Rochester District the structure is a broad anticline that dips to the south. The rocks forming the western limb of the anticline have a general strike of N. 30 deg. W. and dip 30 deg. westerly. Accompanying the intrusion of the granitic rocks were heated sediments that introduced the ore and mineral deposits found in the Rochester District.

During the following geologic periods erosion was active denuding the mountain range and depositing the débris in the valleys. Towards the close of the Tertiary Era extensive faulting began to relevel the mountains and continued to the present, as is evidenced by recent scarps at the base of the range and the steep walled canyons that dissect the range. This latest movement has been accompanied at times by the outpouring of basaltic lavas.

The greater part of the rocks exposed in the Rochester District are Triassic lavas belonging to the Koipato group. Knopf (23, p. 16) estimates their thickness as between 10,000 and 15,000 feet. In Limerick Canyon the rocks are chiefly trachytes and keratophyres intruded by irregular areas of aplite and dikes of granite porphyry.

The trachyte, as described by Knopf, comprises a series of tuffs, and volcanic breccias; light colored, felsitic, and usually containing inconspicuous phenocrysts of microcline only, although quartz phenocrysts occur in the upper layers of the series. Where the lavas are usually massive, the tuffs and breccias are more schistose.

Near the head of Limerick Canyon an area of the trachyte was little altered and Knopf found in a study of the darker colored rock that it had numerous slender phenocrysts of microcline in a sparsely ground mass, the spherulites dusted with minute specks of iron ore. In addition, minor amounts of apatite, titanite, and zircon were present. A small amount of secondary quartz occurred as veinlets and replacement of some of the microclines. A fresh specimen of the rock was analyzed by R. C. Wells (23, p. 16) with the following results:

SiO ₂	67.01%
Al ₂ O ₃	15.97%
Fe ₂ O ₃	2.54%
FeO	.44%
MgO	Trace
CaO	.19%
Na ₂ O	1.92%
K ₂ O	11.42%
H ₂ O	.28%
TiO ₂	.39%
Total	100.16%

¹U. S. Geol. Explor. 40th Par. Rept. vol. 1, p. 203, 1878.

high percentage of potash and relatively low per-
indicates that the rock is a trachyte.

of Lincoln Hill a considerable area of the trachyte
illy altered and replaced by quartz, sericite, andalu-
rite. The underlying breccias strike N. 20 deg. W.
westerly. The dumortierite occurs as lavender to
the schist and as a network of quartz-dumortierite
al texture of the trachyte has been completely oblit-
ck consists of the four minerals mentioned. Knopf
s the alteration of the trachyte is due to the action of
boron that escaped from the underlying granitic
d and solidified.

es are dark colored tuffs, breccias, and lavas, with
lbite, chlorite pseudomorphs after pyroxene, and
ue to metamorphism the keratophyres are largely
abundance of black tourmaline and biotite. The con-
phyres and trachytes is somewhat uncertain as they
through a transition zone of from 500 feet to one
thickness.

intrusive rocks were recognized, a meta-diorite of
es and granite-porphyrries of post-Triassic age. The
lieved to be responsible for the solutions that depos-
rite and metalliferous veins.

f dumortierite in Humboldt Queen Canyon occur
the canyon at an elevation of approximately 5,500
l and about 1,000 feet above Oreana. The road from
ss the flat floored Humboldt Valley to the foot of the
ses rapidly due east through the steep-walled canyon.
of the Champion Porcelain Company, the canyon
n canyon turning south, with a branch to the north
le continuing east.

te occurs in two parallel zones striking east of north

The western zone, located at the fork of the canyon,
old outcrop of massive quartz several hundred feet
de, striking N. 20 deg. E., and dipping 55 deg. west-
lopment work has been done upon it as yet. The
bout 600 feet east from the western zone and con-
rthern branch of the canyon. This zone is 75 feet
15 deg. E., dips 50 deg. W., and has furnished the
rtierite obtained up to the present time. North and
le, the zone is marked by bold outcrops of massive
hich are numerous stringers and veins of quartz and
the saddle, however, the zone is inconspicuous and
nearly pure, massive dumortierite were found along
e. The greater part of the production has come from
d lenses found in and near the saddle. It is evident
as formed due to the somewhat softer character of
ortion of the zone.

ve been explored by numerous open cuts and shallow
e as it crosses the saddle and by about 1,000 feet of
tunnel driven to intersect the zone at depth. The
follow the zone up the gulch to the north and it
the masses of high grade dumortierite are most

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abundant in an elongate area or shoot pitching about 35 deg. to the south. This shoot lies on the southern end or toe of the large outcrop of massive quartz to the north.

The lower tunnel cut the dumortierite zone about 160 feet from the portal and at 180 feet intersected a diabase dike that at the time seemed to be the footwall of the zone. The tunnel then was turned to the north and followed the dike for 300 feet. At this point it became apparent that the dike had crossed the zone at a low angle and a crosscut was driven east through the zone behind the dike. The crosscut is under the southern end of the massive quartz outcropping up the northern branch of the canyon. For the first few feet the crosscut is in altered schist that soon changes to massive quartz which continues for 75 feet to the schist that forms the footwall of the zone. While the massive quartz contains numerous stringers and small lenses of dumortierite, muscovite, and quartz, yet none of the large masses of pure dumortierite were encountered.

A second crosscut was then driven where the tunnel first encountered the dike and on breaking through, a large lense of dumortierite was found. This lense was spindle shaped and about 38 feet long, 12 feet high, and 7 feet wide, tapering at both ends. The longer axis pitched 35 deg. to the north lying across the general pitch of the shoot as disclosed in the surface openings. The lense lay on massive quartz with schist hanging walls and stringers of dumortierite leading from the lense. This seems to be the common mode of occurrence of the lenses found in place near the surface in the saddle.

The course of the diabase dike varies from N. 10 deg. W. in the southernmost exposure in the tunnel, then turns on an arc parallel to the zone for 125 feet, then again turns N. 10 deg. W. cutting across the zone. At the northern end of the tunnel the dike again turns a few degrees east of north and follows parallel to the zone. It is probable that the dike follows more or less closely the hanging wall of the massive quartz but not so closely but that occasional pockets of the soft altered schist and dumortierite lenses are included between the dike and the quartz as in the area where the recent mass of dumortierite was found. Unfortunately the surface is deeply covered with debris and the dike does not outcrop. The westerly dip of the dike varies from 45 deg. to 70 deg., and the width from 20 to 35 feet. As the dike has numerous apophyses cutting across the schistosity and the dumortierite veins and lenses it is evident that the dike was injected after the dumortierite had formed and that its approximate parallelism to the zone is due to the relative weakness of the zone offering a ready avenue of flow than the surrounding rocks.

MICROSCOPIC MINERALOGY

By O. R. GRAWE

in Humboldt Queen Canyon shows a diversity of use of its various modes of occurrence. These may be the main types:

dumortierite of shipping grade, occurring in lenses and as residual surface boulders in the alluvium

in veins and stringers cutting quartz or as fibrous quartz.

in veins and stringers in sericite schist or as fibrous sericite.

It is proposed that it may be feasible to further subdivide classes of occurrence with the specific manner of occurrence of the associations and abundance.

The occurrence of dumortierite is apparent in the quartz. The quartz and quartz fills fractures in the dumortierite. The dumortierite is included in the quartz as fine, fibrous fibers which give their color to the gangue material associated with dumortierite and quartz in such an occurrence. Very often the andalusite can only be distinguished from the aid of a microscope. Mica is a minor associate mineral except where this mode of occurrence grades

into other minerals. Dumortierite occur together in a variety of ways. Granular and fibrous range from a microscopic texture to that of granular aggregates up to a half centimeter in size. In some instances dumortierite veins cut the sericite, in other instances apparently has replaced the sericite along the veins, producing an interlamination of dumortierite and sericite. Subsequent movement has taken place the two have been compressed together so that the rock takes on a foliation. Dumortierite also is found intimately mixed with quartz, and andalusite and as fibrous inclusions in the mica as it does the quartz. Pyrite is a rare mineral associated with dumortierite in the schist.

From a mineralogical standpoint it was considered best to select specimens of the purest dumortierite and describe this dumortierite is like previously described material. The range of colors from intense blue to deep pinkish red. The massive material is mat or dull and the streak is blue. The hardness is between 6 and 7 and the massive material is tough, no doubt, to the close intergrowth of many layers of transparent prismatic crystals without terminal cleavage in the schist but, because of their incompleteness, they have not been studied in detail. They are dull violet blue and gray color 53 V-B. Other properties of dumortierite in Humboldt Queen Canyon have been described by Banks (11) and by Peek (35).

In the following table certain variable properties of the selected specimens are tabulated together with analyses of the

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material as determined by C. W. Davis of the Rare and Precious Mineral Experiment Station of the U. S. Bureau of Mines.

The colors of the hand specimens were determined by comparison with the Ridgway color chart. No tint photometer reading could be made because of lack of suitable material in pieces large enough for the purpose. The streaks were determined both by comparison with the Ridgway chart and by analysis by means of the Tint Photometer according to the method described by the distributor of the instrument and according to the suggestions made by the publisher (Science, n. s., Vol. LXVI, pp. 61, 62, 1927). Material for determination of the streak was prepared by grinding selected fragments of the mineral in an agate mortar to pass a 1/16 mm. sieve. This fine powder was poured on a piece of cardboard approximately 4 square inches in area and rolled smooth under a four kilogram weight. A second piece of cardboard being inserted between the weight and the material during the rolling. This insured a uniform compactness in all specimens analyzed. The cardboard covered by the compacted powder was then placed on the magnesia block of the photometer and color readings were taken in the usual way. The readings tabulated are the mean of five. Specific gravity determinations recorded in the table represent the average Jolly balance determinations of five samples of each specimen.

Davis analyzed three specimens of the dumortierite described above. The material was ground to pass a 200 mesh screen and, in accordance with instructions, no attempt was made to purify it. The general method of analysis was that for silicate rocks outlined by W. F. Schaller (U. S. Geol. Survey Bull. 700, 1919) but modified to take account the precautions of Schaller (44). Titanium was determined colorimetrically, boron according to the Gouch-Low method as modified by Chapin (J. Am. Chem. Soc. Vol. 30, pp. 1691-1701, 1908), and alkalis were determined by the J. Lawrence Smith method.

From the chemical analyses the theoretical mineral compositions of the analyzed materials were calculated. These computations are based on the minerals observed by Jones in his study of the thin sections of the material analyzed. The following assumptions were made:

- (1) That all the K_2O is contained in muscovite ($Al_3KH_2Si_3O_{12}$), av. sp. gr. 2.85.
- (2) That all the Na_2O is contained in paragonite ($Al_3NaH_2Si_3O_{12}$), av. sp. gr. 2.90.
- (3) That all the B_2O_3 , Ti_2O_3 and Fe_2O_3 is contained in dumortierite, av. sp. gr. 3.30.
- (4) That all Al_2O_3 in excess of that needed to form micas and dumortierite produced andalusite (Al_2SiO_5), av. sp. gr. 3.18.
- (5) That all excess SiO_2 formed quartz (SiO_2), av. sp. gr. 2.65.

No account was taken of the MgO which may form some colorless phlogopite. The calculated specific gravities are the sums of the specific gravities of the theoretical minerals weighted according to their abundance.

The first set of mineral analyses is based on Schaller's formula for dumortierite, $8Al_2O_3 \cdot B_2O_3 \cdot H_2O \cdot 6SiO_2$, in which titanium and iron replace aluminum. The results based on this formula are at variance because the calculated percentage of andalusite for specimen 1 is

actually observed in the thin section, which shows andalusite. The per cent of dumortierite is too low. The reason, however, is apparent in the analyses of specimens: there is a notable excess of boron, an excess sufficient to be apparent in the thin sections in some mineral other than andalusite, but such a mineral was not observed by Jones. On Todd's formula, $8\text{Al}_2\text{O}_3 \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O} \cdot 7\text{SiO}_2$, lead to for specimen 1 the following mineral composition was

Andalusite	6.45%
Quartz	2.72%
Dumortierite	59.96%
Staurolite	12.51%
.....	13.01%
.....	94.65%
Sp. gr. 2.99	

Computations did not agree very well with the micro-analyses. Computations were made based on Ford's formula, $(\text{SiO}_2)_7$, which makes allowance for the possible minimum by boron and hydrogen, and of course the minimum by titanium and iron is not ruled out. This advantage that all the boron can be calculated as being further, much more of the water can be calculated in the known minerals. The per cent of dumortierite is in specimen 1 and not notably changed in the other two. The analysis shows the absence of andalusite whereas the analysis is known to be present, the error made is smaller in those based on the formula of Todd and of Schaller. Schaller is correct in saying that the determination of boron loss method yields high results, then it is possible to have Al_2O_3 in excess of that required for andalusite and such Al_2O_3 could be calculated as andalusite. Specific gravities are not notably different, those based on Ford's formula being slightly better. The total mineral composition on the basis of Ford's formula for dumortierite are those based on the formulas of Todd and of Schaller. In conclusion, it may be stated that the mineral composition of dumortierite as computed from chemical analyses agrees with the observed facts when the percentage mineral composition is based on Ford's formula for dumortierite.

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ANALYSES OF DUMORTIERITE FROM GYPSY QUEEN CANYON, NEVADA

Number of sample Color of hand specimen (Ridgway) Color of streak (Ridgway)	1				2		3		4	
	Tourmaline pink 67 th V-R b Pale rhodonite pink 71 st V-RR f		Light vinaceous purple 65 th RR-V b Pale vinaceous lilac 69 th RV-RR f		Dark lavender 61 th VR-V b Vinaceous lavender 65 th RR-V f		Grayish violet-blue 53 rd V-B i Grayish lavender 57 th VB-V f			
Streak color as determined by the Ives Tint Photometer	82.5	77.0	72.0	67.0	65.5	60.0	62.0	60.0		
Percent admixture of black as calculated from photometer readings	71.5	62.0	60.0	60.0	62.5	62.0	39.01	3.13		
Specific gravity (Jolly Balance)	26.86	2.99	3.26	3.23	36.29	3.23	62.0	60.0		
Chemical analysis ^a Results in per cent	SiO ₂	40.83	37.10	33.24	67.0	65.5	62.0	60.0		
	Al ₂ O ₃	47.67	53.63	57.42	62.0	60.0	62.5	62.0		
	Fe ₂ O ₃	0.14	0.18	0.15	0.15	0.15	0.15	0.15		
	TiO ₂	0.66	0.72	0.72	0.72	0.72	0.72	0.72		
	B ₂ O ₃	3.15	4.80	4.80	4.80	4.80	4.80	4.80		
	CaO	None	None	None	None	None	None	None		
	MgO	0.13	0.13	0.13	0.13	0.13	0.13	0.13		
	Na ₂ O	0.22	0.22	0.22	0.22	0.22	0.22	0.22		
	K ₂ O	0.76	0.76	0.76	0.76	0.76	0.76	0.76		
	H ₂ O (<110° C)	0.38	0.38	0.38	0.38	0.38	0.38	0.38		
Mineral analysis calculated from chemical analysis using Schaller's formula for dumortierite Results in per cent	H ₂ O (>110° C)	6.18	2.65	2.65	2.65	2.65	2.31	2.31		
	Total	100.11	99.95	99.95	99.95	99.95	100.10	100.10		
	Muscovite	6.45	2.97	2.97	2.97	2.97	2.88	2.88		
	Paragonite	2.72	2.72	2.72	2.72	2.72	2.97	2.97		
	Dumortierite	67.26	80.92	80.92	80.92	80.92	86.72	86.72		
Calculated sp. gr.	Andalusite	12.53	None	None	None	None	None	None		
	Quartz	15.71	11.41	11.41	11.41	11.41	5.87	5.87		
	Total	94.67	98.02	98.02	98.02	98.02	98.44	98.44		
	Excess B ₂ O ₃	None	0.25	0.25	0.25	0.25	0.62	0.62		
	Excess MgO	0.13	0.15	0.15	0.15	0.15	0.11	0.11		
Mineral analysis calculated from chemical analysis using Schaller's formula for dumortierite Results in per cent	Excess H ₂ O (>110° C)	5.07	1.25	1.25	1.25	1.25	0.82	0.82		
	Muscovite	2.97	3.14	3.14	3.14	3.14	3.18	3.18		
	Paragonite	6.45	2.97	2.97	2.97	2.97	2.88	2.88		
	Dumortierite	67.26	80.92	80.92	80.92	80.92	86.72	86.72		
	Total	94.67	98.02	98.02	98.02	98.02	98.44	98.44		

Not analyzed

Mineral analysis calculated

PETROGRAPHY

By J. C. JONES

In sections of the dumortierite and associated rocks studied under the microscope. In the material analyzed megascopically by Grawe the dumortierite occurs as elongate crystals, one-quarter to one-half millimeter and one to fifteen microns in width. These are associated with muscovite up to a millimeter in diameter. A small amount of rutile and titaniferous magnetite occur throughout the felt. A small amount of iron stain is present in the vicinity of the titaniferous minerals together with occasional clear spaces are present, filled with sericite. The dumortierite crystals projecting from the ground mass into the clear spaces have rounded tops and occasionally resemble low angled domes. Aside from the relative proportions of the minerals the only essential feature of the three specimens is that in the blue material the dumortierite crystals are intergrown with quartz which is the case in the other specimens.

The material offered a greater variety of minerals and modes of origin of the deposits. Quartz occurs in masses of irregular outline or in mosaics of intimately intergrown crystals with irregular boundaries, a "jasperoid" structure that has replaced pre-existent minerals and rocks. On the other hand, the quartz crystals are euhedral and show no relationship between the orientation of the crystals and the jasperoid structure.

There had four microscopic phases or modes of occurrence: (1) sheaves or rosettes of minute crystals as in the high magnification sections; (2) crystals in and through the quartz, muscovite, and other minerals; (3) these fine crystals of dumortierite were bunched together in rosettes or in brushes when they progressed from the walls of quartz veins into the quartz, but for the most part they were isolated as spots and individual crystals in the ground mass; (4) the ground mass was noted where three lines of crystals were present on the walls in a small quartz vein dividing it into three parts.

The crystals in and through the quartz, muscovite, and other minerals these fine crystals of dumortierite were bunched together in rosettes or in brushes when they progressed from the walls of quartz veins into the quartz, but for the most part they were isolated as spots and individual crystals in the ground mass. The ground mass was noted where three lines of crystals were present on the walls in a small quartz vein dividing it into three parts.

The crystals usually blue and violet in color in conventional and pink shades of the finer crystals. Occasionally the crystals had both blue and pink colors irregularly distributed in the same crystal.

The masses of submicroscopic particles dusting the dumortierite crystals.

The dumortierite occurred in large foils and plates frequently colored pink and blue and included dumortierite. Dumortierite occurred in large flakes but for the most part as minute foils and plates. The usual uncertainty that some of the sericite is dumortierite but none of the latter mineral occurred in large enough quantities to be recognized in the hand specimens.

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Andalusite was observed as large grains up to several millimeter diameter and in all stages of replacement by the minerals mentioned previously. The replacement proceeded along the cleavage cracks started in isolated areas within the crystals and progressed by stages. The preliminary stage was generally a granulation of the andalusite in which the borders of the crystals broke into a dusty aggregate of grains that extinguished in harmony with the unaltered crystal indicating that there had been no movement of the individual grains during the period of granulation. Then needles of dumortierite accompanied by sericite penetrate the granular mass eventually changing it into a mixture of dumortierite and muscovite as observed in the high grade material. Later quartz, sericite, and dumortierite were deposited in irregular patches and in veinlets replacing to some extent the earlier formed minerals. Finally quartz veins with a minor amount of dumortierite and sericite cut through the replaced mass as though the deposit from the solutions causing the alteration of the andalusite.

Minute grains of andalusite the same size as the granules in the granulated andalusite occur in the quartz and in a number of instances they were clearly dragged from the original borders of the large andalusite crystals by the solution as it deposited the quartz veinlets.

Small grains of rutile and titaniferous magnetite, with the accompanying oxidation products leucoxene and iron oxides, were scattered sporadically through the rock. A few instances were noted where pyrite had been deposited in altering andalusite along with the sericite, quartz and dumortierite.

A slide of the rock forming the hanging wall of the east dumortierite zone disclosed residual phenocrysts of microcline and quartz, a few grains of titanite, needles of tourmaline, and small fragments of tuffaceous inclusions with spherulitic texture in a schistose groundmass of granular quartz and sericite. The rock responds closely to the trachyte as described by Knopf.

The footwall rock is somewhat darker in color and is essentially a quartz-sericite schist containing veins of quartz and black tourmaline. The microscope disclosed crystals of titaniferous magnetite and titanite with leucoxene, biotite foils and patches of chlorite, and outlines of feldspar crystals and tuff fragments replaced by a fine-grained aggregate of secondary quartz and sericite. No residual quartz phenocrysts were noted. The rock is similar to the keratophyres.

The rock in the face of the crosscut under the massive quartz is an altered quartz-sericite schist with a few quartz phenocrysts as the representatives of the minerals in the original lava. Along the hanging wall of the diabase dike occasional thin streaks of dark coarse-grained schist occur which have quartz residuals and outlines of feldspar completely replaced with a fine grained aggregate of quartz and sericite. Euhedral crystals of black tourmaline are abundant throughout across the planes of the schistosity and have evidently been formed after the development of the schist.

As nearly as can be judged the zone has formed in the transition zone between the trachytes and the keratophyres where the two types of lavas are interbedded. While no definite statement can be made as to the attitude of the different beds, it is probable that the zone dips somewhat more steeply than the beds and cuts them at an angle.

ORIGIN OF THE DEPOSIT

By J. C. JONES

study of rocks metamorphosed through contact with a several stages can be identified and a sequence in relation be recognized. The data at hand indicates the origin of the deposits in Humboldt Queen Canyon:

1. A series of trachytes and keratophyres forming dykes between the two types of lavas were altered to andalusite by the increased temperature and differential pressure of the intrusion of the granitic magma.

2. A weakness developed cutting the beds at a low angle which served for the transmission of fluids escaping from the intruding magma below.

3. The fluids at first were probably liquid and changed the channels to massive, elongate bodies of quartz with inclusions of andalusite.

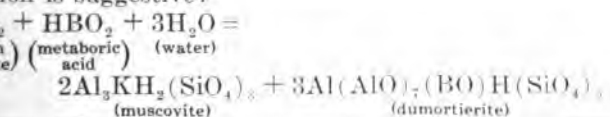
4. Probably gaseous, next introduced potash, boron, and fluorine, the andalusite forming the high grade dumortierite and isolated crystals of black tourmaline found in the

5. Solutions, probably liquid, introduced the quartz, andalusite veins found in the zones and quartz, black tourmaline found elsewhere. These final solutions eventually formed the mineraliferous veins found in the vicinity.

6. The above sketched does not imply any sharp demarcation of the changing conditions under which the solutions formed. The slow cooling of the magma. Our knowledge of the laws governing the processes of solidifying magmas and the alteration of the invaded rocks is so scanty that a definite conclusion is not possible.

7. The study of the reactions of water, potash, and silica at temperatures between 200° C. and 1000° C., was accomplished by studying his results he states that the solubility of silica is very slight and not enough to appreciably affect the reaction. If silica is melted in an atmosphere of water vapor, a small amount of the water will dissolve, depending on the pressure and the freezing point of the silica. As the pressure increases, more water will enter into the solution and the freezing point of the water will be depressed until a second critical point probably at 374° C. and a concentration of silica is reached. At this point the solution is chemically pure water. The addition of potash causes a depression of the critical field and the pressures must be increased. Jones also found that at temperatures above 500° C. no evidence of silica could be found in the solution.

8. The study obtained with the microscope indicated that the reaction of a mixture of dumortierite and muscovite with water is suggestive:



Trans. Am. Chem. Soc. Vol. 39, pp. 1173-1229, 1917.

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As the components introduced into the andalusite are known to be volatile at temperatures above $500^{\circ}\text{C}.$, and to be present in the solutions given off by solidifying magmas it is probable that the solutions were gaseous at the time of the formation of the high temperature dumortierite. The latter introduction of the quartz veins was delayed until the solutions had cooled below the critical temperature of water ($365^{\circ}\text{C}.$) as is indicated by a slight replacement of dumortierite and muscovite. It is possible that most of the dumortierite grains found in the quartz veins are residuals though some may have been deposited with the quartz.

The dumortierite then was formed in two distinct stages; first, replacement of pre-existent andalusite, probably by gaseous solutions at temperatures above $500^{\circ}\text{C}.$; the other by liquid solutions at the critical temperature of water in the vicinity of $365^{\circ}\text{C}.$, and second, deposition of the quartz veins. An examination of specimens from a dozen other localities indicated that in every instance the dumortierite was deposited with quartz, and the first mode of deposition was absent.

As an excess of silica is undesirable in the manufacture of porcelain sought and as the deposit near Rochester is the only one known at present that furnishes suitable material, the inference is clear that only such deposits as have formed through the replacement of andalusite are of present commercial value.

Prospecting for deposits of dumortierite should be confined to areas in the vicinity of granites and other acid magmas in contact with aluminous rocks. Such rocks are present in the Triassic of Northern Nevada and have been intruded in a number of localities by granites. As the lavender color of the dumortierite is distinctive it will probably be first noted in quartz veins associated with the colored mica schists. If in addition bodies of andalusite occur in the vicinity it is probable that a suitable deposit of dumortierite may be found indicated by large boulders and masses of the purer material on the surface.

MINING OF DUMORTIERITE

By JAY A. CARPENTER

Professor of Mining, Mackay School of Mines

time the mining of dumortierite in the United States mine and that is the mine of the Champion Porcelain Company six miles east of Oreana, Nevada. Oreana is the northern Pacific serving the Rochester Mining District, north of Lovelock, Nevada.

time the actual mining of dumortierite at this mine is open-pit work on a hillside. The dumortierite being in the form of small and large boulders occurring either in the few feet in thickness above the schist or projecting from the schist formation. For a detailed description of the deposit is referred to the section of this bulletin devoted to the deposit. For the purpose of describing the mining is sufficient to say that the dumortierite of present occurrence occurs as segregated lenticular masses in a schistose rock of a metamorphosed igneous origin. The boulders occur on the eastern slope of a hill over a width of about 100 feet to 600 feet, the length conforming with the planes of bedding having a general north-south course. The dip of the hill is at 45 degrees to the west which may also indicate the trend of the schist. The dumortierite occurs in this schist much as it occurs in dumortierite pudding. It is interesting to note also that the schistosity of the minor schistosity conforming with that of the schist. The mining of dumortierite for shipment consisted merely of picking boulders along lines of weakness or in short sections using 60% dynamite. The rock was broken just small enough to be packed by pack horses to take it down the steep gulch to where the wagons of R. H. Rowland could then transport it to the mill for shipment to Detroit.

The outcrop of violet or purplish colored boulders was first seen in a location made in 1917 by R. H. (Slim) Rowland. He found narrow silver-bearing quartz veins occurring in the brow of the hill from the outcropping boulders. These large boulders that interested Mr. Rowland but rather than being of a blue mineral that brought to mind the usual blue mineral that his blue mineral might be the elusive silver mineral. Mr. Rowland "found out that the mineral was dumortierite by gathering specimens and after that found out its commercial value." Years later stirred to action by news of the mining of "spark plug mineral" near Bishop, California, the Champion Porcelain Company, Mr. Rowland sent word to that company early in 1925. Dr. Joseph H. Moore, president of the company, visited the property in April, 1925, in appreciation of the size of the deposit and the value of the mineral as a refractory, the property was purchased in 1925. The first carload shipments were made from the property more strictly speaking from the boulders sticking out of the sagebrush.

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Due to the high hardness and toughness of these boulders, fragments of this pretty colored and attractive looking mineral salt the hillsides for a quarter of a mile around the main outcrop result of the blasting of the boulders. A tenderfoot, even today, wonder how such a promiscuously mineralized area could have been undiscovered for so long a time.

By October, 1926, the wagon road had been extended as practical up the gulch and at this point a neat compressor plant was installed. The compressor is an Ingersoll-Rand portable gas engine driven unit of the 10" x 8" type "Twenty," capable of running two or three jackhammers and the No. 33 Leyner sharpener. The forge for the sharpener is lined with a refractory brick of exceptional qualities made for experimental purposes by the Champion Portland Cement Company from the dumortierite of this property.

A 3-inch pipeline of several hundred feet in length transmits compressed air to the lower tunnel and surface workings. A pack of mules packs up the mining supplies and brings down the ore.

The mine foreman acts both as mechanic and shift boss. sharpening the steel he spends his time at the mine workings, watching the eye and ear on the compressor. The reliability of this type of work is shown by the fact that in over a year's operation it has given no trouble in service with only a few cup leathers for repairs.

The dumortierite is a very slow drilling rock because of its combination of hardness and great toughness. A well-tempered machine bit dulls in three to five inches of drilling. It is also a difficult rock to break with sledge hammers.

Short tunnels and open cuts soon disclosed the fact that most of the large boulders were part of an unconsolidated surface overburden ten to twelve feet deep, but a few of the boulders were still partially encased in the schist formation, and one prospect tunnel encountered dumortierite in place in the schist.

To date the surface boulders have been the main source for the shipments, which now totals close to fifteen hundred tons. The boulders varied in size from a few pounds to a couple that furnished one hundred to two hundred tons each. Lately a main open cut has been started, with the idea of removing and sorting the overburden and disclosing an area of the mineral-bearing schist to obtain an idea of the lenticular masses of dumortierite occur frequently enough in the schist to justify mining as an open cut over a considerable area.

At the present time the separation of shipping material is determined by the color and its "heft" checked occasionally by the use of the balance. By breaking with sledges and cobbing, any adhering material is discarded and a very pure product made, having an average specific gravity of 3.05 compared with 3.2 to 3.4 for the pure dumortierite. With the shipment of this pure product there will accumulate a much larger tonnage of second-class material in which the dumortierite occurs as narrow ribbons in schist or as mixed crystalline masses of dumortierite and quartz.

The possible utilization of this material is ably discussed under the section of this bulletin dealing with the ore dressing of dumortierite.

The development of this occurrence of dumortierite at a depth of about 200 feet below its outcrop is being carried on in a lower tunnel.

No. 3. About 1,000 feet of work in this tunnel has shown that the dumortierite occurred in a possible vein in the hanging wall of a diabase dike encountered in the tunnel, but that it did occur in the schist formation on the schistosity below its outcrop, and in the same large masses of pure mineral as on the surface. Development work will be required to determine if the dumortierite masses occur in ever large enough areas at this depth to justify stopping

PROSPECTING FOR DUMORTIERITE

Dumortierite is a silicate of aluminum of less common occurrence than the known similar minerals, andalusite and sillimanite, and is only known as "spark plug minerals" because of their use in spark plugs.

These minerals in that beside the elements aluminum and silicon contain a small percentage of boron.

The occurrence of these three minerals is with highly siliceous rocks. The main characteristics by which they might be distinguished are their dull or greasy luster in massive form, their hardness which is higher than that of quartz, their hardness relative to that of quartz, and lastly, by their color which distinguishes them. Sillimanite is generally enough different from quartz by its color, while in the case of dumortierite color is a distinguishing characteristic. Dumortierite has color but is not of a single color. It varies from a deep blue to pink with shades of purple, lavender and lilac. These three minerals are usually classed as uncommon minerals not easily identified by ordinary analytical facilities.

Who believes he has made a discovery of one of these "spark plug minerals" should try to ascertain for himself if there is a commercial occurrence of no commercial value or if there is sufficient quantity to be profitably mined. He should determine the mineral and enclosing formations for determination in a Laboratory such as, for instance, is maintained at Nevada at the Mackay School of Mines. There is no doubt as to the determinations, but the State expects in return as compensation for the mineral occurrence as the prospector can intelligently catalogue the mineral resources of the

State. He naturally wants to know or should know the approximate value of these spark plug minerals and how nearly pure mineral they are. It is in order to size up the value of his discovery or to put forth to retrace his steps to a mineral occurrence of the quality that he has in mind. The use of these minerals is usually restricted to have reached the point of a steady open market. The Arizona Mining Journal has quoted andalusite at \$100 a ton f. o. b. Philadelphia. This would correspond to \$30 a ton f. o. b. for points west of the Rocky Mountains. The comparative price for "spark plug" minerals in general is such that it is not in the class with rare minerals sold and shipped by express, but more in the class with the common metallic minerals such as magnesite, sulphur, short sheet mica.

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At the present time a high percentage of purity is demanded for mineral as it occurs or as it is mined, is apt to be contaminated by quartz intercrystallized or mechanically held in it, and the same is true of this bulletin dealing with the metallurgical treatment points. It is serious this impurity is in high class refractory work. At the present time the purity of these minerals, such as dumortierite for instance, is judged commercially by its specific gravity. The pure mineral has a specific gravity of 3.2 to 3.4, and carload shipments are received at an average close to 3.1 in gravity. With a more extended use of these minerals for less exacting requirements than that of spark plugs, it may be possible that much more impure mineral may be obtained, probably at a correspondingly lower price. As a whole, dumortierite and its kindred minerals offers, at the least, a very interesting commercial chance of gain to the prospector searching for the more common metallic and nonmetallic minerals.

ORE DRESSING TESTS

By WALTER S. PALMER

Professor of Metallurgy, Mackay School of Mines

From the standpoint there are at least six distinct types of ore in the deposit in Humboldt Queen Canyon, and have been sent to the Mackay School of Mines from the Mendenhall Hill near Rochester. Both of the types found are similar in general to ores found in Humboldt

and ores can be described as follows:

Type 1. This type of ore is the high grade material which can be easily mined, with perhaps a little cobbing and hand sorting, the material coming in lump form and running over 3.05 in specific gravity is considered first-class ore.

Type 2. This type consists of pieces composed of dumortierite surrounded or intergrown with a coarse muscovite or with sericite schist.

Type 3. This type consists of veins of dumortierite, some of which is disseminated in hand specimens, occurring in both sericite schist and quartzite which has been described as type six.

Type 4. This type consists of dumortierite closely associated and intergrown with quartz, running from fairly pure dumortierite to quartz only. Examination of thin sections of this quartzite shows fine needle like crystals of the dumortierite through the quartz, giving it its color.

Type 5. This type consists of dumortierite, both blue and pink varieties, with quartz and sericite.

Type 6. This type consists chiefly of a mixture of quartz and andalusite with dumortierite.

ORE DRESSING TESTS

For the purpose of shipping a specific gravity of 3.05 is considered of shipping tests as have been made up to the present time on the ore. For their object the producing of a concentrate of 3.05 gravity.

The minerals are dumortierite with a gravity of 3.26 to 3.28; quartz, gravity 3.16 to 3.20; muscovite, gravity 2.86; sericite and quartz, gravity 2.65. There are traces of pyrite which might have to be taken into account before a concentrate was produced. Several methods could be used to separate the minerals from the concentrate.

Method 1. This method is similar to Type 1 requires only a little hand sorting and cobbing to produce shipping ore.

Method 2. This method of Type 2 can be raised to the required grade by the lump ore on itself in a ball mill and washing. The ore is quite tough while the sericite is quite soft and is easily dislodged from the dumortierite. It is understood that a little sericite or muscovite is not detrimental of some value in the final product when it is used for spark plugs.

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The first problem in the treatment of ores of Types 3 and 4 appears to be one of so crushing the ore as to liberate the dumortierite, or dumortierite and andalusite, from the associated minerals of quartz is the most important. The quartz and the dumortierite crystals are so intergrown and some of the dumortierite occurs in fine hair-like crystals that it is practically impossible to crush them fine enough to liberate all of the dumortierite. Some idea as to the fineness of these crystals is given by the fact that whole networks of quartz will be composed of crystals less than 0.01 m.m. in diameter, and dumortierite crystals having a diameter of only 0.001 m.m. Tyler Standard No. 300 mesh have an opening of 0.043 m.m. These fine crystals produced two effects which are of importance in concentrating the ores; they tend to raise the gravity of the quartz grains in the crushed product and they also give an apparent color to the quartz, both of which complicate the operation of concentration to produce a clean dumortierite product.

Ores of Type 3 appear to separate into the individual minerals on crushing very much better than those of Type 4 and when a high gravity action results, a concentration of the dumortierite to a high gravity product is easily done. In some of the preliminary tests a concentrate running 3.26 has been made by gravity concentration and it is probable that even higher concentrates can be produced. A microscopic examination of the concentrate so produced shows that it consists quite largely of crystals of dumortierite free from adhering minerals. In fact the extent to which the dumortierite, andalusite, and quartz minerals can be physically separated, especially above 200 mesh in size, will indicate in general the extent to which the material can be successfully concentrated. At the present time only a few tests have been run on minus 200 mesh material. Fine material produced from Type 3 gave successful results but ore similar to Type 4 give inconclusive results on the minus 200 mesh material. More tests are to be run on this type of material.

No definite data is as yet available indicating what grade of concentrate will prove acceptable, and concentrates running 3.0 gravity are now being experimented with by the Champion Company. If concentrate of this gravity can be used it will make possible the utilization of the low grade material which is found at Lincoln near Rochester.

Tests were run using a high gravity pulp in an endeavor to separate a product running over 3.05 in gravity. Galena was used for this purpose because of its high gravity and the fact that we had enough of the mineral for the test. While it was possible to make some separation in this way and raise the product to 3.05 or better in gravity it was decided that other and simpler methods could be used to give equally good results.

Flotation has been tried on these ores but up to the present time the method is only partially successful in raising the grade of the material. Reagents tried have removed fairly clean quartz but have been found which would remove a clean dumortierite or, on the other hand, remove both the quartz and the material containing quartz and part dumortierite.

and that there is little possibility of making a separate quartz and dumortierite by heating, quenching, and

USES

used with andalusite in the manufacture of porcelain. As has been stated the Champion Porcelain Company grades dumortierite from its mine in Pershing County, Nevada, to the Champion Porcelain Company of Detroit. This mineral forms a good basis for refractory material with high alumina content. It has important advantages (3) over andalusite, and cyanite. Dumortierite burns to a white product. Dr. J. A. Jeffery informed the writer that the toughness and electrical resistivity of porcelain made at this temperature range in burning than does andalusite, high fusion point, and porcelain made from a mixture of andalusite and dumortierite has a very low coefficient of expansion. The ware made by the Champion Porcelain Company indicates that dumortierite can be obtained in applications many fold. Greatly improved pyrometer tubes, laboratory ware, and dishes have been made of it. The pyrometer does not become porous or brittle after over a year's use in laboratory ware resists both mechanical shock and sudden temperature change much better than does the porcelain now in use. Using the proper mixture of andalusite and dumortierite, a refractory brick has been made by the Champion Porcelain Company in their own kilns. Bricks made of dumortierite are strong and well and those made of only andalusite sag so that a mixture of the two yields a brick of just the right quality. The known occurrence of commercial dumortierite is too small for its employment in any field other than in the manufacture of plug porcelain.

It has been suggested that dumortierite bearing rock might be used as a monumental stone if large enough pieces are obtainable. This is the case with this material in Pershing County, Nevada, which is a quartz-bearing ore but which might well be used for decorative

and Knopf (23) both suggest a possible use of dumortierite as a precious gem material. The quartz associated with dumortierite in Nevada often contains minute hair-like fibers of dumortierite in the quartz a beautiful rose color, rendering it of gem

OF DUMORTIERITE IN SPARK PLUGS

It is suggested that the use of dumortierite as a commercial mineral is being controlled by one company, the Champion Porcelain Company. To control the only known workable deposit, a brief study of the use and the making of spark plugs would probably interest some readers of this bulletin.

A description has been given the writer in conversation with Dr. J. A. Jeffery, President of the Champion Porcelain Company:

J. A. Woolf, U. S. Bureau of Mines Rare and Precious Metal Station, Reno, Nevada.

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The material as mined is hand sorted if necessary at the mine then shipped to the Detroit plant of the Champion Porcelain Company. Upon arriving at the plant it is bedded in lots of 2,000 tons in a system of parallel rows, each carload being laid out in a lot parallel to and beside or above the previous carload. In drawing material for use cuts are taken across the ends of the rows giving a good average lot of the material.

The coarse ore is first crushed in a jaw crusher to about 1/2 inch in size and is then crushed dry in a ball mill, using chromite balls, to minus sixteen mesh in size. It then passes over a magnetic separator to remove any iron from the ball mill and passes to another ball mill where it is ground with sillimanite porcelain balls. This mill is lined with sillimanite porcelain liners. Crushing is continued until fineness that all will pass a 100 mesh screen and 70% will pass 200 mesh. The material is then sampled and stored.

In preparing the body the ground dumortierite is mixed with andalusite, kaolin, and water and the grinding continued in a ball mill having a capacity of about two tons. Here the grinding is done in batches, and a charge will be ground for about seventeen hours. The slip or ground body will then pass a 300 mesh screen. The material then passes to filter presses where the excess water is removed. The cakes from the presses are stored in an aging cellar for ten days. This aging develops plasticity and gives time for each batch of material to be tested.

From the aging cellars the material passes through two more ball mills before being formed into the blanks from which the spars are made. After thorough drying the blanks are turned on special lathes and given their final form. The tolerance allowed is three-thousandth of an inch. The cores are then glazed and are ready for burning.

The cores are burned in a continuous kiln 300 feet long, at a temperature of 2700 degrees Fahrenheit. It takes four days for the material to pass through the kiln.

The cores are next stamped with the trade mark "Champion X" and then passed through an electrically heated kiln to fix the stamping, by burning the name into the glaze.

The cores are now ready to have the metal parts attached.

S OF DUMORTIERITE SOLICITED

School of Mines wishes to gather as complete a collection of dumortierite as possible and will very much appreciate any samples the readers of this bulletin may have which they care to send in.

Will reciprocate by supplying any information about dumortierite may have to anyone requesting the same.

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CARSON CITY, NEVADA

STATE PRINTING OFFICE : : JOE FARNSWORTH, SUPERINTENDENT
1928

BULLETIN OF
STATE BUREAU OF MINES
AND
KAY SCHOOL OF MINES

RAIL RESOURCES OF
SOUTHERN NEVADA



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FOREWORD

Fourth Session of the Nevada Legislature (1929) created the Bureau of Mines. One of the most important functions is to make available, in the form of bulletins, reliable data on Nevada's mineral resources. This particular bulletin deals with the mineral resources and possibilities of Southern Nevada, and the utilization of Boulder Dam power for the reduction of cost of manufacture of products from these and other mineral resources.

The Nevada State Bureau of Mines is separate and distinct from the Mackay School of Mines, the personnel of the two departments being entirely different. It is from the records and personal investigations of the Mackay School of Mines that the data for this publication were obtained.

This bulletin can be supplemented by F. C. Lincoln's "Mining and Mineral Resources of Nevada" to great advantage. Lincoln's book contains excellent sketches of all of the mining districts in Nevada, geology, production and bibliography — and interested parties will find it authentic and reliable. The book is for sale by the Mackay School of Mines, Reno, Nevada, price \$1.50 per copy.

For information on Boulder Dam power and matters connected therewith, see 70th Congress, Second Session, Senate Document No. 103, entitled "Colorado River Development."

Interested parties may obtain the names of owners of properties and the data contained in this bulletin by writing to the State Bureau of Mines, Mackay School of Mines, Reno, Nevada.

Gratitude and thanks are due the following for their helpful assistance:

Commerce of Las Vegas.

and Harry Howell of St. Thomas.

la and H. A. Shamberger of Las Vegas.

ns and A. J. Robins of Goodsprings.

Officials and employees of the many operating companies in Nevada too numerous to mention by name, and the United States Geological Survey.

JOHN A. FULTON,

Director.

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BOULDER CANYON PROJECT ACT

By GEORGE W. MALONE, *State Engineer.*

Canyon Project Act provides that the construction of the project shall begin if and when the "Colorado River Compact" shall be ratified by the seven States of the basin, or if it shall be ratified by the United States and the water limitation as set down in the bill itself shall be accepted by the State of California through legislative action. The project has now been brought about, and it is expected that construction work on the project will begin in the early

part of 1923, located approximately thirty miles southeast of Las Vegas, about thirty miles from a main line of a transcontinental railroad. Construction of the branch railroad from the main transcontinental line to the dam site will start by October 15 this year, and the estimated time for completion is about 150 days.

The dam will be 550 feet high above the normal water surface, and will impound 100,000 acre feet of water, with installed power plants generating 1,000,000 horse power of electrical energy which, at a load factor of 55%, will mean 550,000 "firm" horse power at the dam site.

The dam and power plant, including 4% interest during construction, is estimated at \$121,900,000, and the bill provides that the cost must be had with the States, municipalities and private corporations to amortize the Government investment over a period of fifty years before construction may begin.

Under the present set-up that 3,600,000,000 kilowatt hours will be generated per year, which would mean a sale price of 1.6 mills per kilowatt hour at the switchboard in order to pay for the Government investment over a fifty-year period and to provide a reserve fund for emergencies, which would mean 50 per cent horse power per year, which is the total cost of the project considered for use of the power in the vicinity of the

dam. It is estimated that the transmission of electricity from the dam to the power markets in Southern California, including necessary lines and service, is estimated to cost from 1.6 to 2 mills per kilowatt hour additional.

The project will be secured approximately 200 miles from the dam at a reasonable figure, and natural gas is available in Salt Lake City.

The Pacific Railroad transcontinental system passes within five miles of the project, a branch line being run direct to the dam, and the project is offered to cooperate in every possible way in the project. It is expected to establish industries within the intermountain region.

It is expected that irrigation works of any kind can be secured at a low cost, taxes are low and labor conditions are good.

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All of these items can be taken up and checked in detail, and the writer will be very glad to furnish detailed information upon inquiry.

There is a report printed as Senate Document No. 186, giving details of the development of the Lower Colorado River, including power costs and full construction details of the Boulder Dam project. This report can be secured from any Senator, Congressman, or from the Bureau of Reclamation, Washington, D. C., direct.

The State of Nevada has requested permission of the Secretary of the Interior for an allotment of one-third of the power developed by the Boulder Dam project, and while the final allocation has not been made, we have every reason to expect that a liberal allocation of the power will be made to Nevada at cost at the switchboard. In this connection it will be arranged so any company desiring to secure a block of power for any purpose may be accommodated without undue delay.

COST TABLE NO. 2—STRAIGHT LINE BASIS
Taken from Senate Document No. 186

At switchboard— Cost in mills per kilowatt hour	At power market (12 per cent line losses)	To States of Arizona and Nevada	To Government for special fund	Cost per hour power year at switchboard
1.990	2.262	\$672,800		\$13.00
2.100	2.386	821,900	\$247,500	13.72
2.200	2.500	956,900	472,500	14.38

The above table of costs, taken from Senate Document No. 186, shows that 1.99 mills at the switchboard will just return the Government investment with interest, and shows the effect on the reserve fund prices up to 2.2 mills per kilowatt hour at the switchboard.



AL RESOURCES OF SOUTHERN NEVADA

PRINTER, *Professor of Mining, Mackay School of Mines.*

use of this survey, the term southern Nevada is used approximately that part of Nevada south of the Mount which in its east-west course, just south of the 38th passes close to Goldfield and Pioche. This term is in central Nevada and northern Nevada, and besides applying geographical division of the State, it covers closely that railroad communication is to the south and whose mining will be most vitally affected by the Boulder Canyon

resources of this section of the State have been excellently by Mr. F. C. Lincoln in his comprehensive book, "Geological and Mineral Resources of Nevada." This book is being published in 1923. Each mining district is treated fully and completely; giving its location, history and dealing with the geology, the types of ores and ore bodies. The prominent mines and mining companies are mentioned. A very detailed bibliography is given to aid further

of this description then is not to go into similar detail, but to supplement such detail by serving as an up-to-date quick-reference of these resources, with special emphasis upon their utilization when the Boulder Canyon project offers low rates of power in their development and processing.

Many lines of industry, attracted by the magnet of cheap power in the immediate vicinity of the power plants of the Boulder Canyon, will wish to investigate the possibilities there for their own industry.

Important questions arising will be that of whether or not the information necessary for their particular industry can be obtained

This summary is to give this information concerning the resources of southern Nevada in a condensed form that can be quickly consulted by interested capital without being burdened in technical terms or detailed descriptions.

Of equal importance is to indicate to the prospector, the mining engineer and the mining company the mineral resources and the areas that are apt to be the most greatly benefited by the power, and conversely to indicate those minerals in large enough and pure enough deposits, would most advantageously be having at hand a cheap source of power.

The information for this condensed economic summary of the resources of southern Nevada, a detailed inspection trip was made, much information was received from miners and prospectors, and many samples taken for the U. S. Bureau of Mines Museum and for analyses.

And thought also has been given to determining in

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advance, if possible, the most likely industries that will be established in southern Nevada due to the combination of cheap power and certain natural resources.

Since this summary will be consulted mainly by those interested in some particular mineral resource rather than some particular district each mineral resource of importance is considered separately and given a prominent heading for the reader's convenience. The non-metallic resources are placed first, followed by the metallic resources.

LIMESTONE AND DOLOMITE

Limestone formations are one of the most frequent occurring types of formations in the great area of sedimentary rocks that cover southern Nevada. Limestone is especially abundant in the immediate vicinity of the Union Pacific Railroad all the way across the State including particularly the Las Vegas to Jean territory just north of the site of the power plant of the Boulder Canyon dam project.

The limestones vary in chemical composition from impure shaly limestones, to dolomitic limestones and limestones of high purity, and this latter class is quite abundant in the vicinity of the railroads.

In the past, neither the smelting industry nor the building industry has been large enough in southern Nevada to cause the erection of a number of small lime kilns with attending limestone quarries as was the case in central Nevada. However, with the growing demand for lime in construction work in southern California a lime quarry with small vertical kilns was opened up in 1912 alongside the railroad at Sloan, 17 miles south of Las Vegas. Being cheaply mined by open bench method and lowered to the kilns alongside the railroad and there burned into a high grade lime, this limestone enterprise had sufficient advantages to develop into a stable producer. It is now the property of the U. S. Lime Products Corporation, and is equipped with two rotary kilns to handle about 200 tons of limestone a day.

The analysis of the limestone is given as:

SiO ₂	0.65
Iron oxide and alumina	0.46
Magnesium carbonate	1.70
Lime, as carbonate	97.19

Recently a new limestone quarry has been opened up at Jean Nevada, by the Blue Diamond Company of Los Angeles, and trial shipments of the limestone made to the company's large vertical kiln at Los Angeles.

In the limestone areas there are also beds of dolomite of high purity. One of these beds lies directly over the limestone bed that is being mined in the Sloan quarry. This dolomite is now being mined by the company, burned in two vertical kilns, and hydrated. The properties of this hydrate, sold as the "Boulder Canyon" brand, have been found to be so favorable that a third kiln is being added to supply the demand. The analysis of this dolomite is given as:

	Per Cent
Acid insoluble	0.21
Iron oxide and alumina	.44
Lime (CaO)	30.05
Magnesia (MgO)	21.80
Ignition loss	47.50

power, many chemical industries need also a cheap source of limestone to obtain the alkali, calcium oxide, and the gas, carbonic oxide (given off during the burning of dolomite).

That good sources of limestone and dolomite occur near the future power plant at Black Canyon.

CEMENT-MAKING MATERIALS

For making Portland cement such as pure and shaly limed clays occur in great quantity alongside the Union Pacific Railroad.

There has not been a sufficient use of cement in the territory to justify the erection of a cement plant to compete with the northern and southern California plants. The building of a cement plant at Black Canyon, with subsequent industrial plants, would justify the erection of such a plant.

The lime quarries mentioned can find, or already have, a market close by on the railroad, and the necessary gypsum can be obtained from producing mines close by.

GYPSUM

Gypsum occurs in great abundance in southern Nevada, not only along the Union Pacific Railroad but also close to the vicinity of a town along the old St. Thomas to Bitter Springs and a wagon road.

The quality varies from impure gypsite and impure gypsum to fairly pure selenite and pure gypsum. A high grade has been mined close to the Union Pacific Railroad for over twenty years to supply the plaster trade of southern California. After the war four quarries were all producing and other deposits are being explored by pit or diamond drill. At the present time the Gypsum Company and the U. S. Gypsum Company are both producing, 12 miles southwesterly from Las Vegas.

MAGNESITE

Magnesite occurs in the vicinity of St. Thomas as large deposits of pure magnesite. One of these sedimentary beds roughly parallels the railroad between St. Thomas and Moapa to the southwest about 6 miles away. This sedimentary bed is of surprising steeply enough tilted to offer an easy attack from the surface in open-cut mining. It is close enough to the railroad for a direct short branch line.

The occurrence of similar magnesite lies about 17 miles south of St. Thomas and across the Virgin River. This particular deposit is on the surface of low hills and sides of gulches, which is favorable for cheap mining.

Although the tonnage is immense but, as in the case of other magnesites, it is not a pure magnesite as it contains both iron and silica in a greater percentage than is now considered.

When taken to the southwest of the railroad breaks with a conchoidal fracture, but when placed in water resembles a clay in the sense that it forms a colloidal slime or pulp. In fact, the first

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use of this magnesite was probably by the Indian for his clay for pottery making, as the remnants of charcoal fires and pottery indicate this. The only shipments made to date of this magnesite were those of the pottery makers as a pottery clay, and the shipping spur was named Kaolin.

The peculiar physical properties of this magnesite, coupled with its large and easily mined tonnage close to the railroad, taken in connection with the possibilities of cheap electric power from the Boulder Dam project, offers an interesting chemical and industrial problem.

A description of this occurrence of magnesite, with analyses, can be found in the U. S. G. S. Bulletin No. 798 entitled "Geology of the Muddy Mountains." Since this bed of magnesite outcrops in many gulches over a distance of several miles, there is a possibility that the outcrops be carefully sampled and drilled, that certain sections of the outcrop might be found to be much freer of impurities than the well-known outcrop near Kaolin siding.

The magnesite to the southeast of St. Thomas is a harder rock in comparison with that just mentioned, and breaks down in water much less readily. It contains, as a whole, less impurities in the magnesite itself, but the closer association with dolomitic limestone and beds of clay would make very careful mining and sorting necessary to maintain a product close to the present-day required analysis. The greater distance from the railroad is also an additional handicap.

It has been reported that there are sedimentary beds of magnesite in the vicinity of the West End borax mine, which is only 10 miles northwesterly from Boulder Canyon. This I was not able to confirm.

There is a good possibility that a body of pure magnesite ore might be found in the southern end of Nevada if a vigorous search by prospectors was inaugurated by the simple expedient of a bona fide offer of a cash purchase of the discovery. The great area of dolomitic limestones and dolomites is a likely prospecting ground, in view of the beds of sedimentary magnesite already found.

As an illustration, within the last two years there has been discovered 30 miles northeast of Luning, which is near the new United States Navy munition depot at Hawthorne, a deposit of great tonnage of very pure brucite, the hydrate of magnesium. This deposit outcrops prominently on a granite and dolomite contact and was walked over for years by prospectors in search of precious metal ores.

With the advent of the airplane, and the continued search for an extended use of lightweight alloys in all power generating machinery, there is an expanding use of the lightweight metals such as aluminum and magnesium. Commercial deposits of aluminum and magnesium ores in the vicinity of cheap electric power at Black Canyon will surely be of future value, and will eventually attract manufacturing capital to them.

GLASS AND FOUNDRY SANDS

Sandstone beds of great thickness occur in southern Nevada, especially in the vicinity of the Valley of Fire. It is a deep red fantastically eroded sandstone that gives the Valley of Fire its name.

Within a few miles of the Union Pacific Railroad from Las Vegas to Moapa, also on the branch line from Moapa to St. Thomas, and probably more extensive than this, are beds of sandstone of a cream

tly yellowish color composed almost entirely of pure of uniform size.

glass and foundry industries in southern California the last two to four years, a search for suitable sands Nevada to compete with imported Belgian sand, sands California and other localities in the United States.

several trial shipments have been made, and at the present is being operated four miles west from a spur on the of Overton. A shallow overburden is removed, the loosened by explosives, pulled by a drag line into auto hauled to the railroad where it is disintegrated, screened before shipment. A second pit or open cut is being opened in vicinity but about four miles farther from the railroad than operating pit, with the ambitious idea of a future line from the railroad.

his industry is on a close margin basis, with a chance to succeed for special purposes are found and if favorable tariff come about along with cheap electric power. A systematic dis- c- close beds of sandstone equal to the high-priced sand of Illinois.

GRAVEL AND ROCK FOR CONSTRUCTION PURPOSES

beds of sand and gravel near the railroads, highways and generally they are covered with surface soil and somewhat

There are pits all along the gravelled State highway, Arrowhead Trail, crossing the southern end of Nevada. There is no large pit producing high-class washed sand and efficient demand will bring this about. Las Vegas wash, located between Las Vegas and Black Canyon, is an old quarry that can probably furnish an unlimited source of sand for concrete work.

with igneous and sedimentary rocks close to the railroad carried for large scale concrete work.

in the high cliff now exposed above the railroad at W. S. Lime Products quarry, gives an ultimate compressive strength of around 12,000 pounds per square inch.

of sand, gravel and rock will be thoroughly investigated by the United States Government before building the Black Canyon. Wherever points these materials are obtained there also are good sources for future use.

BAUXITE, ALUNITE, ALUMS AND CLAYS

the aluminum mineral that is commercially used for the production of the metal aluminum in connection with cheap electric power. In past years, the discovery of a bauxite deposit at a place in southern Nevada would be of commercial value. The coming cheap electric power from the Boulder Canyon project of past years discoveries of bauxite have been claimed, but records kept, and at the present time there is no deposit on which any work is being done.

hydrous aluminum sulphate containing soda or potash. In southern Nevada. It occurs in some quantity just over

Railroad Pass, 20 miles out on the road from Las Vegas to Black Canyon. As alunite was one of the mineral associates of the rich gold ore at Goldfield, quite extensive underground development work was at one time carried on at this Las Vegas deposit in the hope of finding gold ores in paying quantities.

Since it was mainly sodium instead of potassium in this alunite, it did not compare favorably with the alunite of Marysville, Utah, which during the war, was calcined to recover potassium sulphate with aluminum oxide as a by-product.

Water soluble alums also occur in southern Nevada. About 9 miles beyond Railroad Pass on the road to Black Canyon and then 3 miles southerly, there is a most interesting occurrence of soluble alum salt with some sulphur, in weathered igneous rocks in two belts 300 to 600 feet wide, having an easterly and westerly strike.

The alum salts, at least over the surface and for a distance down to 50 feet, occur in great abundance in the crevices of the finely disintegrated rock. A shaft bottom discloses considerable pyrite in the firmer rock and the surface weathering of this rock evidently gives the alums.

Clays occur in considerable abundance in southern Nevada. Certain deposits on the Tonopah and Tidewater Railroad are being worked quite extensively for use in the oil industry for oil clarification. None of those along the Union Pacific have as yet been found suitable and sold for that purpose, or for use in making China clays or refractory brick. In fact, no use has yet been made of them for even making common brick. Considering the high cost of lumber and cement at Las Vegas there should be a fair chance of success for a well-located brick plant, as common brick is an ideal building material for a warm desert country.

At present there is considerable experimental work being carried on with the idea of the acid treatment of clays to free the aluminum oxide as a source of aluminum, which process is of interest in connection with these clay deposits and cheap electric power.

BORATES

Borax ores in the form of colemanite deposits occur in commercial quantities in southern Nevada in close proximity to Boulder Canyon. Both the Pacific Coast Borax Company and the American Borax Company at one time held or worked deposits here, but the premier deposit of colemanite in this vicinity, and that of the Pacific Coast also, was purchased and put on steady production by the West End Chemical Company. It is now handicapped by recent low prices for borax products, due to increased production from Searles Lake brines and the Kern County water soluble borax mineral, kernite.

In this connection, there are between Virgin Valley and Black Canyon certain bitter springs, sink holes, and old lake beds that suggest their geological study with the idea of drilling test holes in search of beds of soluble salts. One of these lake beds, 10 miles from the railroad on the West End Chemical Company's trucking road, has a remarkably extensive surface deposit of selenite. A 50-foot shaft is still in this crystal selenite, pure except for about 8% of admixed clays.

SALT

Salt occur in the lower end of Virgin Valley below St. Thomas. A close to the Colorado River may eventually be flooded and waters of the Black Canyon dam. The deposit of special value at present is just four miles south of St. Thomas on the west side of the valley, just above the projected shore of the lake that may cover St. Thomas and extend up to the large magnesite deposits.

Into the future of this salt deposit on the shores of the lake is particularly interesting when one visits the salt near the marks and evidence of the prehistoric mining of the pre-Pueblo Indians, the remains of whose villages of the valley near St. Thomas are of keen anthropological interest.

There is a large bed of salt of great thickness and of high value for the inclusion of a small and varying amount of red pigments. The salt can be secured of the clearness of plate glass. It is mined on a close margin by means of an adit and a room-and-pillar method of mining. The salt, after crushing and washing, is shipped to the Los Angeles market.

A deposit of large size lies beyond the Bitter Springs Hill, from this deposit, and there is a probability of other deposits near to Boulder Canyon.

Salt may be of much greater economic importance with the low-cost electricity, for the reason that the electrolysis of brine to obtain sodium hydrate and chlorine is a rapidly growing chemical industry.

SULPHUR AND PYRITES

Large deposits of massive iron pyrites are important as a source of sulphuric acid which is the most used of all acids in chemical industry. There are no known deposits of sulphur in southern Nevada. There are quartz veins carrying a very high percentage of sulphur in the Key West and Bunkerville districts, but no massive sulphur. There is a mixed sodium and calcium sulphate deposit of immense tonnage six miles south of St. Thomas.

BARITE

Barite is reported at Goodsprings. The recent use of the white colored barite for oil well heavy specific gravity muds has stimulated prospecting for off-color barite along the railroad.

FELDSPAR

Feldspar has recently been opened up just within Nevada, near the railroad at Nipton, California. This feldspar deposit is about 200 feet wide and exposed for considerable length.

OTHER NONMETALLICS

Minerals such as phosphates, graphite, asbestos, mica, talc, etc., have not been reported as yet in any promising quantity in Nevada.

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NITRATES, AND FIXATION OF NITROGEN FROM THE AIR

Commercial deposits of nitrates are unknown in southern Nevada. Small local impure beds probably occur in the neighborhood of Death Valley.

The present source of nitrates, outside of Chile, is not from natural deposits of nitrates, but by either their recovery from distillation products of coal or from the fixation of nitrogen from the air. This latter method has been made commercially possible through the use of *cheap electric power* for air liquefaction to obtain nitrogen and for the electrolysis of water to obtain hydrogen, and from the two to obtain ammonia.

The recovery from coal products is the prevailing method in Belgium, Germany and in our eastern States, but the plants for the fixation of atmospheric nitrogen exist where electric power is available at a cost of 2 to 2½ mills per kilowatt hour or less. This is particularly true of Norway, where new plants are going in at the present time. A large plant is in course of erection by the Consolidated Mining and Smelting Company of Canada, in British Columbia, for the purpose of manufacturing fertilizers. It will use 33,000 horse power in the fixation of nitrogen from the air as ammonia.

With the growing agricultural and chemical industries on the Pacific Coast and with low-cost power at the Black Canyon power plant without transmission costs, the future prospects of nitrogen fixation plants and electrochemical and metallurgical plants in Nevada near the power plant should be bright enough to cause their careful investigation by interested capital. This listing of the Nevada mineral resources close by is made with the hope of aiding such investigation.

These plants may not be erected even in the first decade following the completion of the power plants, but the Boulder Canyon project like the Panama Canal, is not only to serve this generation but the generations to follow.

Farsighted corporations will obtain a foothold as soon as practicable. The excess or "dump" power of the early years of operation of the power plant may be a deciding factor in the early establishment of such industries.

Although the maximum year-round steady supply of power for over a long period of years from the proposed power plants can be safely set at only 550,000 horse power of electric energy, the power plant is to have sufficient units to generate a million horse power. Until the upper basin States begin to utilize a large share of the Colorado River basin waters allotted to them, and until auxiliary dams are erected below the Black Canyon dam to supply the wide variation in seasonal demand for irrigating water, until then, it is estimated that the power plants will generate a great excess of power over the 550,000 firm horse power. The sale of this firm horse power at 2 to 2.5 mills per kilowatt hour at the power plants, along with other sources of revenue is estimated to produce sufficient revenue to pay all operating costs along with interest and amortization of the investment.

Under this condition it is a matter of interesting speculation as to how low a figure this excess or "dump" power could be contracted for.

the future need for such industries I quote here from John E. Teeple, of New York, to the American Chemical Society in *Industrial and Engineering Chemistry* of October, 1926. Teeple was awarded the Perkin Medal of 1927 as a "distinguished chemist," mainly because of his close connection with the successful recovery of potash at Searles Lake.

We can predict with certainty that in the future there will be a continuous growth of the chemical process of the fixation of nitrogen in the further chemical process of making phosphate rock and other products for food. Today we are using only about 1,500,000 tons of nitrogen a year. Most of us shall probably live to see the day when 30,000,000 tons of nitrogen are taken from the atmosphere by some nitrogen fixation method."

Teeple says: "Chemical progress, however, is developing many new processes which are more effective and more convenient than acid and alkali. New catalysts, reactions at high pressure, and reaction temperatures such as the electric furnace. By means of these new processes we are just opening the field of large scale synthesis." In this scholarly address on "Economic Factors in Chemistry," he states: "The five important factors are raw materials, technically trained personnel, and 'educated' labor. A country can have a well-developed chemical industry if it can do so and takes the necessary measures. Italy is not helped by nature with any of the five important economic factors. Italy is a good example of a country that seems to have succeeded in building a chemical industry, and she has made great progress."

This is pertinent to Nevada's opportunity if she avails herself of the power from the Boulder Canyon project. The mineral resources will adjoin the dam and power plant. A transcontinental railroad will have a branch line to the project. The future industries located there with the access to the markets of the Pacific Coast.

COAL, OIL AND NATURAL GAS

Nevada, like Italy, is lacking fuel resources of her own. Discoveries of coal, oil or natural gas have been made in the past quarter of a century, does there appear to be that there will be. The best substitute is low-cost electricity to electric furnaces and electric heating devices. Low-cost coal can be purchased from large producing mines within 300 miles from Black Canyon, and within the same distance California crude oil and natural gas are available. They are now being piped long distances, as from Wyoming to Los Angeles and from near Bakersfield into San Francisco.

METALLICS

Iron Ores

Iron ore deposits in southern Nevada of sufficient quantity to be of commercial value. Several occurrences of iron ore have been reported, but upon investigation these occurrences

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proved to be either only a heavily iron-stained siliceous rock, as in the neighborhood of Boulder Canyon, or quite a pure iron oxide, but very limited in quantity, as in the mountains 10 miles northeast of Las Vegas.

There is a reported occurrence of a large body of iron ore on the Utah-Nevada line, 40 miles from the railroad. There are large bodies of high-purity iron ore close to southern Nevada in both Utah and California.

Manganese Ores

Many carloads of manganese ore were shipped from Las Vegas during war times. The producing mines were only 17 miles south-easterly from Las Vegas.

The grade of ore shipped averaged over 35% manganese, with a very low iron content and quite a high silica content of 9% to 15%. The ore contained also 1% to 2% lead and 1 to 2 ounces of silver.

There were two producing companies holding adjacent claims on practically the same outcrop. The claims were located in 1917, but a very limited amount of development work has been accomplished as all early efforts were centered on shipping, followed by a complete shutdown after the war.

The ore is 8 to 19 feet thick, with a flat pitch and a well-defined strong hanging wall, all of which is conducive to cheap mining. The workings resemble a coal mine in appearance and method of mining.

The unfavorable feature during the time it was being mined was the necessity of sorting the ore to better than a 35% manganese or 55% manganese dioxide content in order to show any profit after shipping to eastern points. This sorting, with rejection of the greater part of the ore, would prohibit its mining at the present time.

The faces as now exposed will probably average 20% in manganese. Due to lack of development there is a dearth of positive ore tonnage, but there is a large probable tonnage of a half million tons, and an excellent opportunity for churn drilling beyond present exposures to increase this tonnage.

At the present time there is no process adaptable for the economical recovery of manganese, at present prices, from low grade siliceous ore of this kind, but experimental work is being carried on by private and Government research laboratories.

The type of experimental work that best applies to this particular ore is that of reduction in the electric furnace, due to the closeness of the deposit to the future power plant at Black Rock Canyon, only 10 miles away. This source of cheap power and the size of the ore deposit justify experimental work on the ore.

While production was limited to the one locality at the Three Kings and International mines, other discoveries and locations were made in the same vicinity, and a deep well drilled for Senator Miller about 10 miles westerly was reported to have gone through a thick bed of similar "black ore" at 600 feet in depth. With the closing of the producing mines interest in manganese died out, leaving an unproven territory worthy of prospecting and developing at some future time when the present ore bodies can be profitably treated.

Outside of this one district no other discoveries of manganese ore

located in southern Nevada, but across the Colorado River in the Williams River country engineers have reported millions of tons of manganese ore.

Nickel Ore

The occurrence of nickel reported in southern Nevada is in the form of a nickeliferous silicate ore of the Key West mine, about 15 miles west of Primm and east of the Virgin Valley. Theoretically the nickel content is sufficient to be a valuable constituent in the ore, but it has been a handicap due to the penalty imposed upon the ore for its concentration, and also to the absence of any western market for the nickel mineral be separated into a concentrate.

Tungsten Ore

There has been reported from the southern end of the State since the World War there were operating tungsten mines at Mina on the western and Pioche on the eastern end of the State. The largest producer of tungsten concentrates at present is at Mill City, in Pershing County. The concentrates must be shipped east to Niagara Falls and reduced in electric furnaces. The present rising price of tungsten is resulting in new development work at old properties.

Vanadium Ores

The occurrence of vanadium minerals has been reported from several localities in the southern end of Nevada. These minerals are of secondary importance to other minerals in the same ore, but they are found in its neighborhood, which is about nine miles west of Goodsprings and close to the State line, the vanadium is in sufficient quantity to be considered of primary importance. The ore is termed a vanadium ore.

The principal minerals are vanadinite and descloizite, which are associated with lead and lead and zinc with vanadium, and these minerals are associated with other lead and zinc minerals, both sulphides and silicates in a limestone gangue.

Geological problems and possibilities of this particular ore have been studied by the United States Bureau of Mines. (Reference: Investigations. Serial No. 2433.)

It has not been bright enough to justify an exploration to determine how large a tonnage could be developed of a grade of 2.5% vanadium oxide. Tests indicated that the ore could be concentrated with a 70% recovery to a grade that would in turn be of smelting grade. The cost of shipping a concentrate to the east, or to Germany, coupled with the expense of settlement on such a difficult concentrate to treat, is a hindrance for its production at present.

The concentrate is usually smelted in electric furnaces, and with the cheap power in Southern Nevada for mining, milling and smelting, the possibility of an increased selling price for vanadium ore may result, at some time, in a brisk development campaign to develop the vanadium resources of this district.

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Cobalt Ores

Cobalt has been reported as found both in the Goodsprings and Key West districts in minor quantities associated with other metals. Shipments of cobalt ore have been made from Goodsprings.

Platinum

The presence of platinum in mining districts is so often heralded but so seldom proven to be there. Two authentic occurrences of platinum have been found in the southern end of Nevada. The Boss mine at Goodsprings made shipments of a gold-platinum-palladium ore of high value, but a sufficient amount of the ore could not be found to make a profitable mining venture.

In the Key West mine the copper and nickel bearing ore contains platinum, but not in sufficient quantity to obtain pay for the platinum under present smelting contracts.

Copper Ores

From a copper standpoint, southern Nevada lies between the big copper producing district of Ely, Nevada, to the north, and like districts in Arizona, but apparently lacking in similar large low grade copper deposits itself. It is true that copper is found in several mining districts of southern Nevada associated with other metals, but usually of minor economic importance itself. In four districts, however, the copper content of the ores is an important factor.

The Searchlight district has produced a half million pounds of copper, due mainly to the copper occurring in gold ores. With the possibility of higher priced copper and cheap power, the properties where copper predominates over the gold in value may be worthy of considerable exploration work.

The Yellow Pine district has produced, mostly during the war period, over three million pounds of copper from small oxidized ore bodies in limestone. The abundant deposits of lead and zinc ores in this district carry practically no copper. The Pioche district, including the Bristol district, produced over five million pounds of copper but in this case the copper occurs along with lead and silver ores.

The Key West or Copper King district south of Bunkerville offers the best possibilities of becoming a copper producing district. The combination of copper sulphide ores occurring in an area of granitic rocks with intrusive basic rocks is a favorable one.

Besides copper, the ores contain nickel, cobalt and platinum in quantities sufficient to make the gross value of the ore most attractive when figured upon the selling price of the separate metals.

However, the metallurgical and economical problem of separating and marketing the metal contents profitably is still unsolved. This holds back the exploration of the several good surface showings in the district. The one mine, the Key West, that has been developed to over 200 feet in depth indicates the possibilities of large sized ore bodies in this district.

The Eldorado district, which lies between Searchlight and Black Canyon, is worthy of mention as a possible future producer of copper ores. The district is credited with a gold production of over \$2,000,000 under very adverse circumstances as to location and transportation. The geological formations are favorable for base metal ore bodies, and

undeveloped prospects showing sulphides of copper. It is only 18 miles to the north, and with a branch line led to it and a power plant there, the base metal ores of this district may interest capital.

Zinc and Lead Ore

Lead ores are here considered together, because in southern Nevada they generally occur in the same districts. One marked exception is the Potosi mine, 100 miles north of Las Vegas, that, to its credit in mining, is shipping a lead-silver ore free of zinc. The Jack Rabbit district, near Pioche, has been a consistent lead-silver-copper ore with a negligible amount of zinc, and is the largest producer of lead in Nevada. It has been known as a lead camp. The surface ores worked here were very rich gold and silver ores, giving a product worth many millions of dollars. Production of the base ores continued until after 1900.

After the war a million tons of lead ores, mainly shipped to Utah smelters. The average grade of this was \$10, but the chemical composition was quite ideal for the war oxidized zinc ores were also shipped. The development in recent years of differential flotation has made it possible to treat the mixed sulphide ores of lead and zinc. In 1928 the largest producer of zinc in the State, and the camp is the milling and smelting of the ore is carried out at the mine in Utah. Cheap electric power in the future might be an important factor in extending mining and milling operations

at Goodsprings, Yellow Pine, or Potosi district at Goodsprings, has 100,000, the premier zinc producing district of Nevada, reaching a production of over 20,000,000 pounds of zinc a year during the war, with about a third as much lead. Outside of the bodies of the Potosi mine, the ore is mainly mixed lead and zinc. The camp has been at a low ebb for over a decade, but the possibilities of differential flotation followed by the treatment of the zinc concentrates to marketable zinc oxide right on the property have resulted in the resampling of most of the mines. The treatment of the carbonate concentrate will be for the electric power will probably not be a determining factor. The mine has large reserves of low grade sulphide ores, mainly of the combined acid and electrolytic method of treating the concentrates, depending largely upon a low cost for electric power, the sulphide concentrate such as the Potosi would produce. The Cybo mine north of Tonopah is now producing and shipping for treatment.

CONCLUSION

It is concluded that low-cost power will stimulate the development of the mineral resources of southern Nevada, and conversely these minerals will furnish the necessary raw materials for many future industries located to Nevada by the low-cost power from the Boulder Dam.

LETTER TO GEORGE W. MALONE Re CHEMICAL
INDUSTRIES AT BOULDER DAM

RENO, NEVADA, September 25, 1929.

MR. GEORGE W. MALONE, *State Engineer, Carson City, Nevada.*

DEAR MR. MALONE: In compliance with your request following our discussion of chemical industries that might reasonably be expected to be interested in power developed from the Boulder Dam project, I should like to mention two in particular, viz, first the fixation of atmospheric nitrogen through oxidation of ammonia obtained by direct union of nitrogen and hydrogen, and, second, the reduction of certain ores.

The danger and expense connected with the transportation of large quantities of high explosives from eastern factories to the Hawthorne depot will undoubtedly prompt investigations into the possibility of the manufacture of certain of them, at least, in the west. Since nitric acid is the basic substance used in their preparation, the location of a factory might easily be determined by the possibility of obtaining cheap nitric acid. There appears to be no doubt that its synthesis from ammonia obtained by the fixation of atmospheric nitrogen using the Haber principle of direct union of hydrogen and nitrogen, will become the leading method of manufacture. According to recent figures given in *Industrial Engineering Chemistry* 19, 789-794 (1927) it can already be obtained more cheaply in this way than from Chili saltpeter. The raw materials used consist of nitrogen, oxygen and hydrogen. The first two are best obtained from the atmosphere. While hydrogen may be obtained by several different methods, it is claimed by many that with reasonably cheap electric power it can be produced economically by the electrolysis of water. If this be true, it should be possible to manufacture such explosives as T. N. T. and nitrocellulose, as well as many of the war gases, by utilization of electric power developed at Boulder Dam.

The large deposits of nearly pure sodium chloride (halite) found in southern Nevada would permit of a further decrease in the cost of the hydrogen by electrolysis of its solution rather than of water, since two valuable by-products, sodium hydroxide and chlorine, are obtained. The extensive use of sodium hydroxide in the refining of petroleum and in connection with the fruit industry of California should provide a market for it, and since the chlorine industry is developing along the line of its production by this process, it is evident that a sufficient outlet for the chlorine would insure the practicability of the production of hydrogen by the electrolytic process. In view of the wide variety of uses chlorine has, and the fact that it forms an important material in the manufacture of war gases in addition to the possibilities it offers in the metallurgical industry, makes it very unlikely that its disposition would be difficult. The conditions, therefore, appear to be very favorable for the manufacture of many of the explosives handled at the Hawthorne storage plant by use of electric power developed at Boulder Dam.

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CARSON CITY, NEVADA

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1929



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STRICT, NEVADA

THOMAS B. NOLAN
ogist, U. S. Geological Survey

Y THE NEVADA STATE BUREAU OF MINES
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MACKAY SCHOOL OF MINES

UNDERGROUND GEOLOGY OF THE EASTERN PART OF THE TONOPAH MINING DISTRICT, NEVADA

By THOMAS B. NOLAN

Associate Geologist, U. S. Geological Survey

AND PUBLISHED BY THE NEVADA STATE BUREAU OF MINES
IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY



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GROUND GEOLOGY OF THE WESTERN PART OF THE TONOPAH MINING DISTRICT, NEVADA¹

By THOMAS B. NOLAN

INTRODUCTION

In 1929 the Nevada State Legislature appropriated \$10,000 to be expended on geologic and topographic work in cooperation with the United States Geological Survey during the years 1929-1930. The Nevada Mine Operators Association advised that one of the projects undertaken under this appropriation was a geologic resurvey of the Tonopah mining district, in Esmeralda and Lincoln Counties. The writer was assigned to this work and carried on field work from July 11 to October 25, 1929. During this period the readily accessible workings of the district in the western half of the district were examined. These workings include the Tonopah Extension Mines, Inc. (Victor, Cash Boy, McKane, and Extension No. 2 shafts); West End Mining Co. (associated West End Extension Co. and Tonopah 76 and Ohio shafts); MacNamara Mining Co. (MacNamara shaft); Tonopah Midway Mining Co. (New Midway and Midway shafts); Jim Butler Mining Co. (Wandering Boy, and Fraction No. 2 shafts); Tonopah Mining Co. (Sand Grass, Red Plume, and the country west of the Silver Top shafts); and Keystone Mining Co. shaft. This report is based upon this examination and summarizes the preliminary conclusions reached. These conclusions are subject to revision after the workings in the eastern half of the district are examined—a task which it is hoped will be completed during the field season of 1930. It is planned that a final report on the district, which will include the geologic map, will be published as a professional paper of the United States Geological Survey.

The writer desires to acknowledge his appreciation of the excellent cooperation shown by the officials of all the companies in the district in their indebtedness to them for the details of the geology of the district, which is not now accessible. He also wishes to acknowledge the assistance of Ian Campbell and J. W. Vanderwilt, and the suggestions and criticisms made by H. G. Ferguson, J. H. Allen, and W. C. Mendenhall during their several brief visits to the district. Mr. Campbell has also provided for this report the results of his microscopic study of the rock specimens

¹By permission of the Director, U. S. Geological Survey.

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PREVIOUS GEOLOGIC WORK

By far the greater part of the geologic work in Tonopah represented by published reports has been done by J. E. Spurr. His first work there was done in 1902 and 1903, and is covered by Professional Paper 42 of the U. S. Geological Survey, published in 1905. He also visited the district in 1908 to examine the West End and MacNamara mines professionally, and returned in 1910 to study the Belmont, Montana, Midway, and Tonopah Mining Co. properties. He was made an officer of the Tonopah Mining Co. in 1912 and remained in Tonopah for more than three years. Two publications represent the investigations made during the two later visits.¹ The following extract from the second of these papers summarizes his final conception of the geology

At Tonopah the oldest rock is a trachyte flow highly altered to quartz-sericite, and adularia. The lower part of this flow is a fine flow-banded glassy trachyte. The main body of the trachyte contains the oldest and by far the most important group of mineral veins; the glassy trachyte appears practically barren.

Stresses subsequent to the trachyte extrusion produced horizontal fissuring near the zone of transition between the main body of trachyte and its glassy lower portion; and along here an andesite (Sandgrass andesite) intrusion penetrated. After renewed fissuring along the same zone, a glassy trachy-alaskitic intrusion (Montana breccia), very full of inclusions, took place, usually following along immediately above the andesite. Subsequent movement reopened this line of weakness, and a second trachy-alaskitic intrusion came in—the West End rhyolite sheet—which penetrated along a fissure usually lying immediately above the Montana breccia. At a subsequent epoch came an eruption of andesite (Midway andesite) as a surface flow; at a still later epoch there was a series of rhyolitic and alaskitic surface flows and intrusions, of which the most important in the mine workings is a great intrusive mass called the Tonopah rhyolite.

The principal veins were formed after the trachyte eruption and before the Sandgrass andesite-Montana breccia-West End rhyolite intrusions. They are quartz veins carrying silver and gold. A second set of veins was formed after the West End rhyolite intrusion and before the Midway andesite eruption. This second set is divided into four successive groups—A, large typically barren quartz veins; B, tungsten-bearing veins; C, mixed quartz and adularia veins, typically barren; D, productive veins like those of the first set following the trachyte. A third set of veins was formed after the Tonopah rhyolite intrusion. They are quartz veins carrying occasional lead, zinc and copper sulphides.

All these veins formed at shallow depths, and the different types are held to represent various stages of temperature. The first-period veins represent the normal shallow-seated type, and followed the trachyte eruption; the second-period B veins probably represent an abnormal

¹Report on the geology of the property of the Montana-Tonopah Mining Company, Nevada, published by the company, 1910; Ore deposition at Tonopah, Nevada; Econ. Geology, vol. 10, pp. 713-769, 1915.

y sustained temperature, following the trachy-alaskitic
e second-period D veins a subsequent briefly sustained
perature more normal to shallow depths; the third-period
gh but briefly sustained temperature following the alas-
n rhyolite) intrusion. No vein formation followed the
ion.

of faulting is long and complex; important movements
nce at every stage of the geologic history. These move-
ments and were due to the volcanic disturbances.

earlier, Burgess¹ reached a radically different con-
that formed by Spurr as to the nature of the several
disclosed by the mining operations. He considered
evidence shown by the formations is that in which they
—in other words, that the different formations
surface flows or accumulations of volcanic mate-
questioning Spurr's conclusion that many of these
are intrusive. Burgess also notes that many of the
veins continue downward into the West End rhyolite,
es, although he does not so state, that the mineral-
ization of the two portions is contemporaneous.

It has also been briefly discussed by Locke,² who in
agrees with Burgess that the formations are present in
the stratigraphic sequence. Locke also questions the
of Spurr's statement that the mineralization occurred at
several epochs, and notes that "There is no mineralogical
evidence whatever to be made between many veins which,
under the hypothesis [Spurr's] should belong to different

Recent contribution to the geology of the district has
been made by Bastin and Laney.⁴ These authors confined their
study chiefly to a study of the ores, and did not concern
themselves with either the stratigraphic sequence or the geologic
history of the district. With regard to the ores, however, they
note mineralogic differences between veins of supposed dif-
ferent ages, but are commonly no greater than may be observed in
the veins of one continuous vein. * * * Upon the sole
basis of mineral composition and texture of the primary ore
there is but little reason for the impartial geologic observer
to distinguish the principal productive veins as of more than one age."⁵

A., The geology of the producing part of the Tonopah mining
district, *Geology*, vol. 4, pp. 681-712, 1909.
Bastin, The geology of the Tonopah mining district: *Am. Inst. Min.*
Trans., vol. 43, pp. 157-166, 1912.

Bastin and Laney, F. B., The genesis of the ores at Tonopah, Nevada:
Geol. Soc. Amer. Prof. Paper 104, 1918.

The results of the previous work may perhaps be very briefly summarized as follows: The district is underlain by a series of volcanic rocks, which are considered by Spurr to be in large part intrusive sills and by Burgess and Locke to be entirely of surficial accumulation. All these observers imply that these formations are relatively flat-lying and that their essentially horizontal continuity is disturbed only by faulting, the cause of which is attributed by Spurr to volcanic activity and is considered by Burgess to be in part a reflection of the irregularities in original distribution of the formations. Spurr postulates a number of different periods of ore formation, a view which is directly challenged by Locke, indirectly questioned by Burgess, and not supported by the work of Bastin and Laney.

Spurr, Burgess, and Locke all appear to agree in the fact that the "Midway andesite" is later than the period of ore formation and acts as a capping to the ore.

SUMMARY STATEMENT OF RESULTS OF PRESENT INVESTIGATION

During the 15 years or more that has intervened since the last work by Spurr, Burgess, and Locke there has been a considerable amount of development work done in the western half of the district, which has reached to much greater depths than in the old central portion. This new work has disclosed a number of features of the geology that are not readily apparent elsewhere, and as a result, the writer's conception of the geologic setting at Tonopah is in part rather widely at variance with the views expressed by earlier writers. The points of difference may be divided into three groups—those relating to the stratigraphy, the structure, and the ore deposits.

The sequence of formations in the western part of the district is as follows: The oldest unit is that called by Burgess the "Lower rhyolite" and by Spurr, in his 1915 paper, the Tonopah rhyolite; for this unit the writer proposes the name Tonopah formation. It consists of interbedded rhyolitic flows, tuffs, breccias, and well-laminated silt composed largely of volcanic material, and is locally cut by dikes and small intrusive masses of similar composition. Interbedded with the Tonopah formation at two or more horizons are dark lavas, for the most part keratophyric, which are identical with rocks mapped by Spurr as the Sandgrass or "calcite" andesite. Similar rock exposed in the lower portions of Sand Grass and Extension No. 1 shafts may perhaps be an intrusive plug into the Tonopah formation. The next younger formation is the Mizpah trachyte, which might

accurately a keratophyre. This formation probably the Tonopah formation conformably, but in most contact between them has been a site for the intrusion of a sill-like mass long known as the West End rhyolite but younger than the West End rhyolite but younger than the others is an intrusive mass of breccia, here named West End breccia, which appears to have been intruded along with the ore. Only two other formations, both of which appear to be older, have been recognized in the underground workings. Earlier is the Fraction breccia, elsewhere considered as a part of the Esmeralda ("Siebert") formation. As the other formations, is cut by intrusive dikes of rhyolite, which are presumably similar to the Oddie rhyolite dacite defined by Spurr. The writer was unable to distinguish the "Midway andesite," generally supposed to be the ore, in any of the underground exposures examined.

Development of mining westward has brought to light a great deal of information concerning the geologic structure of the district. In regard, particularly, some of the conclusions here presented may be considered as preliminary in nature and dependent upon the detailed mapping of the eastern half of the district.

In general, the formations have been tilted to the westward-dipping monocline, the observed dips in which vary from 10° to 20° more in some localities. The dip on the whole is toward the east, and there is a suggestion, based upon the deeper workings from the Midway and Mizpah, that after passing through the horizontal it reverses, and dips to the east. The tilted formations are cut by a compound fault, whose appearance in cross section is a concave crescent, convex upward. This fault may be considered a transverse fault along which the upper side have moved eastward for a total distance of 1,500 feet. There are in addition a number of faults of considerable throw, that cut the crescent-shaped fault and represent several successive movements.

The occurrence of ore is intimately associated with the unusual structure described in the preceding paragraph, in that almost all the ore that have thus far been mined appear to be localized along the fault itself, in faults that are hanging wall faults, or in faults, many of them of almost insignificant throw, that roughly radiate from its crest. The factors governing this localization of ore shoots are probably

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several in number, and their relative importance is not known. The writer's present view is that at least three factors must have been operative during the formation of ore in any of the fractures above mentioned—(1) the fracture must have been situated above a certain isotherm (line of equal temperature) existing at the time of ore deposition; (2) it must have been open to the passage of solutions at that time; and (3) the wall rocks of the fracture must have been permeable to the solutions. Specific applications of these factors are discussed on a later page. The presence of quartz appears to have little or no bearing upon the localization of ore, and the writer believes that the bulk of the silver is of distinctly later introduction.

In addition to the ore deposits in fractures related to the main fault, ore has been found in three faults of later age. In each of these three, however, the strike of the productive part is close to the general strike of the other productive fissures—nearly east and west.

THE FORMATIONS

Tonopah formation—The name Tonopah formation is proposed for what has been previously called the "Lower rhyolite."¹ The formation has also been called the "Tonopah rhyolite" or "Tonopah rhyolite-dacite"² and correlated with rhyolite exposed on the surface north of the mining district. These exposures have not yet been studied by the writer, but from the descriptions of the lithology and relations they do not appear to be in any way related to the beds here discussed. The formation as here defined includes rocks that have been mapped previously as "Glassy trachyte" and "Montana breccia," but it does not include all the exposures that have been so assigned by Spurr, Burgess, and others.

The best exposures of the formation are found in the western workings of the Tonopah Extension mine, notably on the 1,200-foot, 1,540-foot, and 1,880-foot levels. Less extensive but equally significant exposures are present in the 1,050-foot level from the Extension No. 1 shaft, the 1,000-foot and 1,140-foot levels of the Sand Grass, the 700-foot level of the Mizpah, and the 800-foot and 960-foot levels of the West End. The formation may also be seen in many of the workings of all the other mines studied, but in these extensive alteration has generally served to mask its true nature.

¹Burgess, J. A., The geology of the producing part of the Tonopah mining district: Econ. Geology, vol. 4, p. 687, 1909.

²Spurr, J. E., Geology of the Tonopah mining district, Nevada: U. S. Geological Survey Prof. Paper 42, p. 41, 1905; Ore deposition at Tonopah, Nevada: Econ. Geology, vol. 10, p. 745, 1915.

ding feature of the formation is that it is composed of a sequence of volcanic breccias, massive tuffs of various size, porphyritic flows, banded flows, and water-laid material of several kinds, the most striking of which is probably laminated material that closely resembles much of the formation.

As described by Burgess¹ as bedded pyroclastic material in this formation, and the exposures in the Tonopah Mining district add abundant proof of the nonintrusive character of these rocks. Bedding planes are apparent in many places, and in numerous specimens there is an obvious transition from coarse-grained material at the bottom of a bed to fine-grained material at the top. On one bedding surface well-developed ripple marks were noted. In addition, the fact that the formation is interbedded with amygdaloidal flows of Sandgrass makes it almost certain that the great bulk of the formation is a surface accumulation.

Small intrusive rocks are, however, included within the formation. It will be expected in such an accumulation of dominantly volcanic debris. One of the clearest examples of such an intrusion is a strikingly porphyritic dike that is exposed on the west side of the Sand Grass, in the shaft crosscut, about 100 feet from the footwall of the vein. Other small intrusive dikes of porphyry and breccia may be found at several places. These breccias are probably related to the intrusive rhyolite breccia, but it has not been practicable in all cases to relate them certainly with that body.

Flow-banded rhyolites are interbedded with the other rocks of the formation in almost all exposures. This rock has been identified by some of the geologists who have visited the area as "Glassy trachyte." The writer, however, found it difficult to separate this rock satisfactorily because of its interbedding in many places with tuff and breccia. Conchoidal fracture is locally marked.

Campbell has studied a number of specimens of this rock under the microscope and has submitted the following description of them:

Specimens of the flow-banded rock phenocrysts are not common. Biotite is found occasionally, and altered biotite more commonly. The matrix is everywhere much altered, either to quartz or to a siliceous material, and its original character is therefore uncertain. None of the sections studied is now glassy, although originally it

¹, op. cit., pp. 687-689.

may have been partly to wholly glassy in a few places. The writer believes that for the most part it was originally holocrystalline. The altered matrix consists of extremely fine to medium-grained feldspathic material, sericitized and in part silicified to greater or lesser extent. Flow structure is common, and in a few sections there is suggestion of a trachytic texture. Apatite and zircon occur as very small accessories.

Quartz veinlets are the most striking feature of most sections. They appear to have been formed by replacement along the more permeable zones of the flow. Adularia occurs in these veinlets, but is by no means common. Sericite is generally present, especially along the middle of the veinlets. Another set of quartz veinlets, mostly mere threads, is found roughly at right angles to the main banding. These seem to be low cracks along which there has been a slight offsetting of the main bands. Pyritization of these rocks has been very common.

The elastic character of the breccias and tuffs is unmistakable in most thin sections. These rocks consist typically of angular fragments of quartz, orthoclase (both sanidine and adularia), albite, and very rare microcline and microcline microperthite in a fine-grained groundmass which appears to consist mostly of feldspathic material. Quartz is the most abundant of the larger fragments. Apatite (colorless) and zircon occur sparingly.

In some of the finer-grained tuffs the peculiar concave trilobate structure known as "eutaxitic texture" is well developed, indicating that the fragments were originally glass. They have since been altered to secondary quartz.

Alteration has affected these rocks in much the same heterogeneous fashion as it has the other formations of the district. Carbonatization and chloritization were perhaps the commonest types; but sericitization, silicification, and adularization have also occurred. Pyrite is widespread but not particularly abundant, and much of it is partly altered to siderite.

The bottom of the formation has not yet been exposed by the mining operations. In all but a few places its top is marked by the intrusive West End rhyolite, which separates it from the Mizpah trachyte. On the 1,330-foot level of the Midway mine, however, the intrusive is absent, and a normal contact between the Tonopah formation and the Mizpah trachyte is exposed. The beds are steeply tilted at this place, and the mine workings show that the two formations interfinger with each other, beds of breccia or breccia alternating with relatively thin layers of typical Mizpah trachyte.

As the base of the formation is nowhere exposed, its true thickness is not known. Approximately 1,000 feet is present in the western part of the Tonopah Extension mine, exclusive of the interbedded Sandgrass andesite.

The age of the formation is not definitely known. It is unconformable beneath the Esmeralda formation, of upper Miocene age.

fragments of black slate that presumably belong to or Ordovician, inasmuch as lithologically similar recent areas are known to be of lower Paleozoic age.¹ Portions of the Sandgrass andesite and Mizpah trachyte which are of essentially the same geologic age as the formation, are rich in albite and are similar to rocks at localities in Nevada that Knopf² has described as "tertiary." Almost all these rocks are of Mesozoic age but the formation at Cedar Mountain⁴ is considered to be Tertiary. In composition may be used as a basis of correlation, the formation may be either of Mesozoic or Tertiary age. H. G. Spurr studied the Mesozoic rocks in the Tonopah and Pahrump quadrangles and has also seen the exposures of the formation underground, and he informs the writer⁵ that they are not at all similar in appearance. It would appear, therefore, that the Tonopah formation is of Tertiary (rather than upper Miocene).

Andesite—In Spurr's earliest examination of the rocks belonging to the Sandgrass andesite were considered an altered phase of the Mizpah trachyte and were called the "calcitic phase of the earlier andesite." When the formation was recognized as distinct from the Mizpah trachyte, the name was shortened by those working in the district to "andesite."⁶ In his final publication Spurr proposed "Sandgrass andesite" for the formation, and this name was adopted in the present report, although microscopic study has shown the formation contains relatively little andesite, most being keratophyric.

The formation is exposed in all the mines that were examined in this survey, but its character and relations are best

¹ G. S. G., Geology and ore deposits of the Manhattan district, Nevada: U. S. Geol. Survey Bull. 723, pp. 18-24, 1924. Ransome, F. L., Geology and ore deposits of the Tonopah district, Nevada: U. S. Geol. Survey Prof. Paper 66, p. 32, 1909. H. G. Spurr, Geology and ore deposits of the Yerington district, Nevada: U. S. Geol. Survey Prof. Paper 114, pp. 13-16, 1918; Ore deposits of Cedar Mountain, Nevada: U. S. Geol. Survey Bull. 725, pp. 363-365, 368, and ore deposits of the Rochester district, Nevada: U. S. Geol. Survey Bull. 725, pp. 20-23, 1924.

² Keratophyre in recent years has been applied to essentially unaltered rocks similar to trachytes but which have a sodic plagioclase, albite, in place of potash feldspar as the characteristic feldspathic phase is retained in this report, although the word was originally applied to rocks in which the soda-rich feldspar was developed subse-

³ H. G. S., op. cit., p. 368. Communication.

⁴ H. G. S., op. cit., p. 691.

⁵ H. G. S., Econ. Geology, vol. 10, p. 729, 1915.

observed in the 960-foot level of the West End, the 1,540-foot and 1,880-foot levels of the Tonopah Extension, and the 1,000-foot and 1,140-foot levels of the Sand Grass.

Previous writers are not in agreement as to the true nature of this formation. Spurr considers it to be an intrusive sill-like mass, and Burgess implies that it is a flow, a view that is accepted by Locke. So far as the present examination went, the bulk of the formation as exposed underground is definitely extrusive. This is very clearly shown by the West End and Tonopah Extension occurrences cited in the preceding paragraph. At these localities the formation is composed of a series of flows of different composition and texture, some of which are strikingly amygdaloidal, and is divided into two separate bodies by an intervening strip of the Tonopah formation. The mass exposed in the workings from the Sand Grass shaft, however, is rather uniform in composition and texture and may be intrusive, though, on the other hand, the uniformity may be due to the fact that the workings that cut the formation are nearly parallel to the general strike, and thus expose only a single flow. The relation of this mass to the other formations is in large part masked by the presence of the intrusive Extension breccia.

In the Red Plume mine and in many of the workings from the old Midway shaft the Sandgrass andesite is also exposed. In these localities there is in general rather pronounced crushing and alteration, which has tended to mask the nature and relation of the formation. The boundaries of the formation in this region are somewhat irregular, but it appears most probable that this is due to a combination of an interfingering contact and folding that to intrusion. The interfingering of the andesite with the Tonopah formation may be observed on a small scale on the 530-foot level of the Midway mine; and the fact that folding has affected these two formations is apparent from the dips of the Tonopah formation in the lower workings from both the Red Plume and old Midway shafts.

The formation is dominantly gray-green to dark green, although locally, bands of nearly black basalt are interlaid with it. The bulk of the rock is porphyritic, but in both the basalt and the amygdaloidal portions this feature is not readily apparent. There are also some probable flow breccias in the formation where it is exposed in the Mizpah-Silver Top workings and in the West End mine near its boundary with the Jim Butler workings, but in all these localities the rock is rather thoroughly altered, and the nature of the supposed breccias is obscure.

ll has provided the following notes upon the micro-
s of the formation:

aloidal facies of the formation altered feldspars appear
ss of chlorite. The feldspar phenocrysts are of small to
d, though mostly altered to calcite, appear to have been
y. Ferromagnesian phenocrysts were evidently rather
mygdules show concentric filling by chlorite, calcite, and
is found as swarms of small cubes, but is only rarely
mygdules.

rock consists of about 30 per cent of small tabular fresh
ic andesine in a typical basaltic texture. The ground-
is made up of exceedingly small lathlike feldspars, the
reen which are filled with a fine-grained aggregate of
calcite. Magnetite in small subhedral grains is abundant,
relatively rare. Pyrite and zircon are absent.

from the vicinity of the Sand Grass shaft show a seriate
cture of altered feldspar phenocrysts in a rather fine-
d groundmass. The feldspars are almost completely
te, zoisite, sericite, chlorite, and calcite, but a few rem-
that their composition is that of albite. Other pheno-
abundant and their outlines suggest that they were
blende and very probably biotite. These are now com-
to elongate prismatic forms outlined with a heavy
of black iron oxides, the inner portion of which con-
e and quartz, with locally a little carbonate or sericite.
ss seems to have suffered less alteration than the pheno-
es of small lathlike to tabular feldspars in subparallel
an be distinguished. These seem to be albite chiefly;
ay be a little orthoclase and quartz. Among them can
e alteration products mentioned above, with chlorite and
t abundant. Apatite is fairly common throughout the
f it is the ordinary colorless variety. Zircon was not
occurs sparingly in rather irregular aggregates.

thickness of the formation is not definitely known.
foot level of the Tonopah Extension approximately
exposed, and a portion of a somewhat lower belt is
s lower limit is concealed by faulting. The forma-
of the same age as the Tonopah formation, with
interbedded.

achyte—The rock of andesitic appearance first
Spurr¹ under the name "Earlier andesite," as
ined, also included the Sandgrass andesite, and
1915, he renamed the formation the Mizpah tra-
name is retained in the present report, although
work has shown that albite is the only feldspar

U. S. Geol. Survey Prof. Paper 42, p. 31, 1905.
Econ. Geology, vol. 10, p. 720, 1915.

present, and the rock is in reality a keratophyre or albite trachyte, a distinction first made by Winchell in an unpublished report to the Tonopah Extension Mining Co. On the lower level of the Tonopah Extension mine this formation has been called the Victor andesite.

In several of the mine workings there are exposures of the rock that have been mapped by other geologists as "Midway andesite" or "later andesite,"¹ and described by them as lying unconformably above the Mizpah trachyte and forming a "cap rock" to the veins. So far as the writer's observations in the mines of the western part of the district show, the rocks assigned to the "Midway andesite" cannot be separated from the Mizpah trachyte by reason of any original differences in composition or texture, nor has he seen any examples of this rock capping any of the veins, or found in the literature reference to any specific example of it. In many places, it is true, extensive chloritization has affected these rocks and changed their appearance, but within such altered bodies less altered facies are found to be of the same keratophyric nature as the unquestionable Mizpah trachyte.

The least altered rock of the formation is normally a porphyritic rock of grayish-green or brownish-green aspect. The phenocrysts of feldspar are almost invariably somewhat dulled by partial alteration, are somewhat variable in size and number, and are set in a dense matrix locally flecked with chlorite. Pyritization has been rather widespread. Two other types of rock are found in the formation in a number of places. One of these is a flow-banded rock which is particularly abundant in the Wandersing Boy workings, and is recognized less commonly in the other mines. The other is a fragmental rock, commonly a breccia, but locally tuffaceous, which is generally well-bedded. This variety was recognized in several places, particularly in the region between the Red Plume and new Midway shafts and in the Jim Butler and West End workings in the hanging wall of the West End vein.

Mr. Campbell writes:

In thin section the Mizpah trachyte shows rather numerous and prominent albite phenocrysts, set in a fine-grained, somewhat orthophyric groundmass composed principally of albite and orthoclase. A little quartz in the groundmass may be primary, but it is difficult to distinguish from secondary quartz. In the interstices of the feldspars in the groundmass are scattered small shreds of chlorite and sericite. Ferromagnesian phenocrysts are very rare. Biotite may be inferred from its pseudomorphs, which are generally either sericite or

¹Spurr, J. E., U. S. Geol. Survey Prof. Paper 42, p. 33, 1915; Econ. Geology, vol. 10, p. 743, 1915. Burgess, J. A., Econ. Geology, vol. 4, p. 703, 1909.

ite, much of which is pleochroic, is relatively abundant, but her scant. Magnetite or ilmenite may have been spar- but if so, it is now entirely altered to rutile.

oted above, is the chief feldspar. Its average composi- The phenocrysts are tabular and usually show the antithetic twinning, except where this has been obscured Neither pericline nor carlsbad twinning is particularly al growths are almost unknown. All these phenocrysts a greater or lesser extent. Sericitization of the albite as the most widespread type of alteration. Locally, occurred and there has also been replacement by quartz, lorite. Any two or even three alteration products may single crystal. Alteration of the groundmass is more mate with accuracy. It seems to have proceeded more bat of the phenocrysts, but along the same general lines uch altered specimens are found in which the pheno- ne entirely to sericite, but the groundmass has become grown quartz and sericite, with quartz the more abund- specimens that appear to be but little altered it is com- nlets and nests of quartz or quartz and adularia.

s of at least 2,000 feet of the Mizpah trachyte is the hanging-wall exposures in the Sand Grass and Extension mines. The top of the formation is not t where it is unconformably overlain by the Frac- The Mizpah trachyte conformably overlies the nation and must therefore be slightly younger. .

breccia—The name Extension breccia has been locally istrict for an intrusive mass of breccia whose rela- exposed in the Tonopah Extension mine; and as it o distinguish this mass, the name is retained here. that in some of the previous geologic mapping this s been included either with the Tonopah formation Montana breccia."

er levels of the Tonopah Extension mine the breccia he footwall of the Murray and Merger veins. The inues up to the 600-foot level, but the area of breccia ach level steadily decreases upward, because of the dip of the breccia mass is somewhat steeper than vein. The Extension breccia is also found on the of the combined Murray and Merger veins in the of the Sand Grass and Merger mines, but is by no ately outlined there because of the relative scarcity ings.

ive nature of the mass is clearly shown in only a such as the 1,880-foot, 1,760-foot, 1,680-foot, and ls of the Tonopah Extension and the 1,000-foot

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level of the Sand Grass, the relations in other localities being more or less masked by alteration near the veins. The intrusion appears to have been localized along an earlier fault, striking nearly east and dipping north, within the Tonopah formation. On the 1,140-foot level of the Sand Grass, for example, east of the main body of the intrusive, a narrow dike of the breccia is found in this fault zone, which here separates breccias and tuff of the Tonopah formation from Sandgrass andesite. Still farther east on the 1,050-foot level from the Extension No. 1 shaft, however, the formation is absent from the fault zone. The actual contact of the intrusion is in many places difficult to locate exactly. Rock typical of the breccia passes gradually through a variety of grades in which fragments of the invaded rock predominate, then to one in which they are exclusively present, and finally to shattered rock cemented by thin veinlets of the Extension breccia matrix.

The greater part of the intrusion is remarkably homogeneous in appearance, consisting of fragments of various rock types set in a characteristically reddish matrix containing rounded dark phenocrysts of quartz. The rock fragments included are largely of the Tonopah formation and less abundantly of the Sandgrass andesite and Mizpah trachyte. Not uncommonly small fragments of black shale are also found. Locally it is difficult to distinguish the formation from the breccias of the Tonopah formation, for in the vicinity of veins alteration has masked its relations and obliterated its distinctive characters.

Mr. Campbell's observations on the thin sections of this formation are as follows:

Under the microscope most of the inclusions are banded rocks, trachytic rocks, eutaxitic-textured rocks, and tuffaceous rocks, and can be recognized as belonging to the Tonopah formation. The matrix is not usually easy to separate from the rest of the rock. It seems to consist almost entirely of fine-grained quartz, much of which is probably secondary. Large quartz grains are embedded in this matrix and are much corroded and resorbed. Throughout the matrix there is distributed a faint reddish-brown dust, undoubtedly an iron oxide which must account for the red color observed in hand specimen.

The Extension breccia shows the same kinds of alteration, with sericitization and silicification predominating, that the other formations have.

The maximum strike length of the Extension breccia mass was observed on the 1,880-foot level of the Tonopah Extension mine where it amounted to nearly 1,500 feet. The maximum thickness (at right angles to the strike length) is not known because of the interruptions to the mass by faulting, but it is probably in the neighborhood of 1,000 feet.

on is later than the Mizpah trachyte, for it includes that rock, but it is older than the West End rhyolite, is it. It was probably formed in the same general tectonic activity as the Tonopah formation and its asso-

rhyolite—At the time of Spurr's earlier report the formation had been exposed in only a few shafts and was held to be a part of what is called in this report the Tonopah formation. More extensive exposures, however, proved the rock to be a different rock, and it became known as the "Upper rhyolite" described by Burgess¹ under that name, although he included in it rocks that have since been assigned to the West End formation. The formation was redefined in 1915 and named the West End rhyolite,² a name that is

describes the mass as being a series of flows, in contrast to Spurr's contention that it is an intrusive sill-like body. Mine workings have exposed abundant evidence that Spurr's view is correct. Burgess's interpretation is based on the fact that he included in the West End rhyolite rocks now known to belong to the Tonopah formation. The formation is best exposed in the Tonopah Extension and West End mines, where it is found as a westward-dipping mass between the Tonopah formation and the Mizpah trachyte. By following this same mass is also found in the more easterly workings, however, its thickness is considerably less. On the level of the Midway it is entirely absent, and a contact between the Mizpah trachyte and the Tonopah formation is exposed. After allowing for the extensive subsidence it appears that the intrusive originally decreased in thickness northward and upward. A second smaller mass of rhyolite is exposed in the extreme westerly workings of the district, a short distance in the footwall of the main

The nature of the formation is shown by several exposures. Perhaps the most convincing is the fact that it cuts the Tonopah Extension breccia, which is itself intrusive. At several places between the Tonopah Extension and West End mines the formation apophyses into the stratigraphically overlying Mizpah trachyte, and in some localities inclusions of that rock are found within the rhyolite. The largest of these is the

¹U. S. Geol. Survey, Econ. Geology, vol. 4, p. 692, 1909.

²U. S. Geol. Survey, Econ. Geology, vol. 10, p. 737, 1915.

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long, narrow wedge in the footwall of the West End vein on the 500-foot level of the West End mine. In addition to these large features, the details to be observed at individual contacts exposed in the mine workings can be explained only by considering that the West End rhyolite is an intrusive mass.

The rock most characteristic of the formation has a dense greenish matrix in which are set abundant angular fragments of white chalky rock. The number and size of the fragments vary greatly. Normally they form about a third of the rock and have an average diameter between a quarter and half an inch. Locally, particularly toward the east, they are tiny and in places almost completely lacking. Near contacts, on the other hand, the rock in many places is a coarse breccia, with inclusions as much as a foot in diameter, representing rocks of all the older formations, particularly those of the Tonopah formation. In the MacNamara mine, on the 400-foot level, similar coarse breccias may also be observed as bands within the formation. Wherever these variations in the number and size of inclusions are found in contact it was observed that there is no sharp contact between the two phases, but rather a gradual blending over a distance of several feet. At the contacts of the formation the matrix shows chilling phenomena and is darker in color and glassy in appearance. A faint flow banding may be observed in several places, not only near contacts but within the mass of the formation.

Mr. Campbell writes as follows concerning the microscopic features of the formation:

In thin section the rock is seen to be a very fine-grained but generally holocrystalline rhyolite. Sparse phenocrysts of quartz, albite, and orthoclase are found in a matrix of feldspar (probably orthoclase) and quartz (much of which may be secondary).

The white inclusions so prominent in hand specimens are distinguishable with difficulty under the microscope. The "Glassy trachyte" and associated rocks appear to have furnished the material for the inclusions, because textures seen in a few of the sections are entirely similar to those characteristic of parts of the Tonopah formation.

The alteration of the rock was chiefly sericitization, with an indeterminate amount of silicification. Pyrite is widespread and abundant in this formation, and many of the pyrite cubes are bordered by quartz or sericite. Quartz veinlets in the rock are of widespread occurrence and in many of these adularia is a rather abundant accessory. Sericitization occurs in such veinlets more rarely.

The maximum thickness of the formation appears to be exposed in the West End Extension and Tonopah 76 workings, where the main intrusion appears to be at least 600 feet thick. On the

of the Midway, however, this has decreased to the
and rhyolite intrudes all the formations previously
s, like them, unconformably overlain by the Frac-

breccia—For the formation which was first described
the Fraction dacite breccia and whose southern
the Divide district was renamed by Knopf² the
ite breccia, the writer proposes the simplified
breccia, because at Tonopah the basal portion of
contains locally very large amounts of andesitic-
is, with the result that there has at times been
nfusion as to the proper correlation of the beds.
example, been considered to represent the "Mid-
indeed, all examples of "Midway andesite" cap-
that were seen by the writer proved to be this
of the Fraction breccia.

on is exposed in the workings of the Jim Butler,
West End, West End Extension, Monarch Pittsburg,
6 mines as a generally southward-dipping mass
nably overlies the older formations and the veins.
wer contact of the beds is very irregular, showing
ce upon which they were deposited had moderate
y places the major faults that affect the veins
e exerted a control upon this old surface, for the
s deeper where such faults formerly reached the
dition, relatively slight renewed movement along
ults has resulted in shearing of the breccia.

on as exposed underground is almost everywhere
without any indication of bedding, although in a
rlaminated fine-grained material may be observed.
t with the older rocks it is generally sheared, pre-
result of the later earth movements that imposed
ation its general southward dip. The basal beds
made up almost exclusively of rock fragments
sitic in appearance, although most of them are
eratophyres derived from the Mizpah trachyte.
of matrix in this variety is in many places rela-
nd for the most part the matrix has the same
the fragments. Higher up in the formation the

² U. S. Geol. Survey Prof. Paper 42, p. 39, 1905.
The Divide silver district, Nevada: U. S. Geol. Survey Bull.
1921.

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rock is lighter colored and has a lower ratio of fragments matrix. Of this portion Mr. Campbell writes:

The matrix is light colored, exceedingly fine-grained, and under the microscope appears holocrystalline to hypocrystalline. Fluidal texture has been observed. The aggregate index is lower than Canada balsam and higher than gamma of sanidine. Phenocrysts of quartz and sanidine are abundant, and there are a few of albite and biotite. The sanidine is generally much altered to calcite, the albite somewhat altered to sericite, the biotite also to sericite. There has been some silicification throughout the rock and heavy kaolinization locally. Pyrite, partly altered to limonite, occurs sparingly.

Only a small part of the formation is exposed in the underground workings so far examined, and the determination of the total thickness must wait until the surface exposures have been adequately studied.

The Fraction breccia is considered by Ferguson to be the basal member of the Esmeralda ("Siebert") formation¹ and is therefore of upper Miocene age.

Rhyolite dikes—Dikes of rhyolite were observed in two of the mines examined. On the 1,680-foot, 1,760-foot, and 1,880-foot levels of the Tonopah Extension mine in the vicinity of the Campbell Boy shaft, there is a thin dike which in one place at least cuts cleanly across the veins. Larger masses of similar lithology are exposed on the 800-foot level of the West End and West Extension mines, cutting both the Fraction breccia and the older formations.

In both occurrences the rock is a light-colored, rather fine-grained rock with abundant quartz phenocrysts. Mr. Campbell has examined these rocks under the microscope and reports the following:

In thin section the quartz phenocrysts stand out prominently. They are generally rounded but locally are embayed as a result of resorption and are slightly fractured, and are rather free from inclusions. Phenocrysts of sanidine are common, and in one specimen these show partial alteration to calcite. More rarely albite occurs. An occasional small flake of biotite, now altered to sericite, was noted. The groundmass has been much silicified, as is well shown in one specimen where the secondary silicification has produced "enlargements" of quartz phenocrysts, similar to the well-known quartz enlargements that occur typically in quartzites. If we discount this alteration it seems likely that this groundmass was holocrystalline and composed of quartz and orthoclase. There has been in places a slight sericitization, and local small patches of calcite occur. Some pyrite was also noted.

¹Ferguson, H. G., *Geology and ore deposits of the Manhattan district, Nevada*, U. S. Geol. Survey Bull. 723, pp. 42-43, 1924.

has been made to correlate these rocks with the of rhyolite and rhyolite-dacite described by Spurr exposures.

FOLDING AND FAULTING

Publications on the Tonopah district have described formations as being essentially horizontal¹ and have the bulk of the major faulting was later than the ore.² The more extensive exposures available during examination indicate that these earlier conclusions, for the formations are considerably tilted, and are to have been far more pronounced before mining afterward. The apparent horizontal attitude of rocks in the older central portion of the district is in result of premineral faults.

A diagram included as Plate I of this report (in pocket) shows the principal structural features of the western part of the district. This method of illustration was chosen because it could the relations between dominantly eastward- and northward-striking formations be adequately shown. There are, of course, some objections to the method, one important being that all the mine workings cannot be shown. It is thought that these are outweighed by the advantages. For several areas where there are no mine workings the writer has projected geologic features seen in other areas. In a district where faulting is so widespread, such a procedure, rather a dangerous procedure, and the doubt that such projections is indicated by question marks. The formations as already noted show either flow or sedimentary bedding planes, and these features are abundant to provide adequate information as to the attitude of the rocks in most of the workings examined and to the position of unfaulted contacts from level to level. They show that in the western part of the district there is a regional dip that averages close to 45°. The dips appear to increase toward the east, and on the 700-foot and 800-foot levels some mine low northerly and easterly dips may be seen. On the 700-foot level of the Mizpah mine low easterly dips are seen, thus indicating that the beds are folded into

¹ Econ. Geology, vol. 4, fig. 87, p. 705, 1909. Locke, Augustus.
² Eng. Trans., vol. 43, pp. 157, 159, 1913. Spurr, J. E., Econ. Geol.,
vol. 3, 1915.
³ op. cit., pp. 766-769. Burgess, J. A., op. cit., pp. 709-711.

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a northward-plunging anticline. On the 630-foot level of the M
way mine in the vicinity of the old shaft there is apparently
moderate amount of minor folding on or near the crest of t
anticline, to judge from the divergent dips observed there a
also from the irregularity of the contact between the Tonopah
formation and the Sandgrass andesite.

Faulting appears to have been much more effective in t
premineral deformation of the district than folding. It clear
occurred at several stages, to judge from the relations of t
faults to one another, but practically all of the faulting mu
have occurred during the interval between the intrusion of t
West End rhyolite and the deposition of the Fraction brecc
The only earlier fault that could be distinguished is the near
east-west fault that localized the intrusive mass of Extensi
breccia.

The first major fault formed after the intrusion of the We
End rhyolite was a unique compound fault, here termed t
Tonopah fault, whose appearance in cross section approach
that of a recumbent crescent, convex upward, and whose cre
trends nearly east and plunges to the east. (See fig. 1.) T
fault is economically the most important single structural fe
ture in the district, for it not only has played a dominant pa
in determining the present distribution of the formations b
has been the chief factor in the localization of the ore bodi
in that, together with its subsidiary fractures, it has provid
the courses along which mineralization took place. Ore bodi
along different parts of the fault have received different nam
some of which are shown on the figure.

Figure 1 shows the extent to which the fault has been expos
by mine workings—for considerably more than 1,400 feet ver
cally on its north limb and for nearly 700 feet vertically on
south limb. The junction of the lower branch with the upp
branch on the north is well exposed on the 500-foot level of t
Tonopah Extension mine. This locality is not shown on Plate
The diagram, however, does show the junction in cross secti
between the 600-foot and 660-foot levels of the Tonopah Ext
sion mine, about 500 feet southwest of the Sand Grass sha
The upper branch is apparently unmineralized at this point. T
comparable junction to the south has not yet been found, b
the dips of the two branches indicate that it very probably exist
The crests of these two "anticlinal" branches both plunge to t
east at low angles, ranging from 5° to 20°. The present rather
inadequate exposures of the crest of the lower branch sugges
that it plunges at a lower angle than the upper.

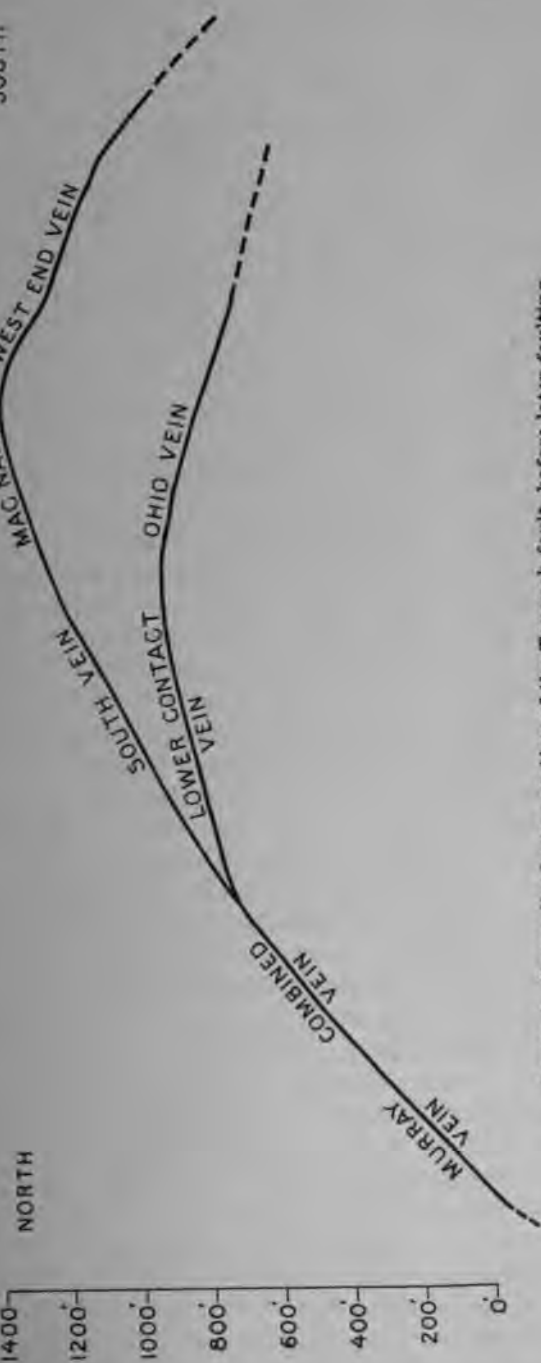


Figure 1—Generalized cross section of the Tonopah fault, before later faulting.

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The appearance of the cross section of the fault suggests once that it is simply a folded fault that originally had a uniform dip. This view is not tenable, however, because there is no similar folding in the formations adjacent to the fault—in fact, as noted above, the axis of the major folding in the wall rocks is at right angles to the axis of the crest of the fault. The throw along the fault may best be measured by the displacement of the nearly northward-trending contacts between formations on both sides of the essentially eastward-trending fault, as is well shown by the contact between the West End rhyolite and Mizpah trachyte on the 1,540-foot level of the Tonopah Extension mine.

The determination of the displacement along the fault, however, is somewhat complicated on the upper levels because of the presence there of a number of subsidiary, related faults that branch from its flanks and radiate from its crest, and because the dip of many of the contacts between formations there decreases rapidly eastward as the axis of the anticlinal fold is approached. On the lower levels the total horizontal shift of an individual contact by the fault and its splits is about 1,500 feet. Less trustworthy information on the upper levels also gives a figure close to this, but here the displacement is divided almost equally between the two major branches that form the crest of the fault.

The subsidiary related faults are most abundant on the upper levels. The only large one found at depth on the north limb of the main fault is mineralized and is locally known as the Mergers vein. Its line of junction with the main fault plunges steeply to the east, and the two diverge from each other to the west. West of the point of junction the displacement along the main fault decreases by about one-half, the remainder being along the branch fault. No comparable branch or split has yet been observed along the south limb of the Tonopah fault.

The radiating faults along the crest of the fault differ from those on the flanks in that their lines of intersection with the main fault are nearly horizontal and their divergence is in the vertical rather than a lateral horizontal direction. Several of these fractures have been developed in the property of the Tonopah Mining Co., although most of them have only a very slight throw. The principal one is that occupied by the Mizpah vein and by its probable extension to the west as the Red Plum Extension North vein. The latter has a maximum vertical displacement of several hundred feet, which, however, as in almost all the others of these faults that are sufficiently well developed, decreases rapidly, both upward and westward. This feature

well shown along the Mizpah vein in the workings of the Tonopah shaft, the Extension North vein in the Extension and the Egyptian vein in the Extension and West Extension. As the throw decreases the fracture generally dips, and in many places splits into two or more branches. This is particularly well exhibited along the Valley Extension and Mizpah vein.

The manner by which the Tonopah fault was formed is not understood. It must have developed in essentially its present position for the wall rocks fail to show any comparable folding, and hence it is obvious that the movement along the fault is essentially horizontal. It also appears probable that its development is closely connected with that of the northward-trending anticline, although the anticline is clearly earlier, its axial plane being also offset by the fault. However, it is not known whether the fault was formed as a result of differential pressure developed after the folding and is therefore in the nature of a secondary fault or flaw, or whether it represents a slump, foliation, or a piling up of volcanic material near the surface during the folding, or whether it was formed in some other manner. The apparent absence of drag effects near the fault supports the second view.

In the western part of the district, some other prospects of sufficiently great economic importance to warrant mention in this preliminary report. These may be divided into four groups of different ages, each group characterized by different strikes and dips. There are many other faults in the district, but they have not caused any confusion in the veins.

A group of faults that cut the Tonopah fault trend west-northwest and dip at a moderately low angle to the east. Two faults have been placed in this group, the larger and the smaller. The more westerly has been developed in West End Extension and Tonopah 76 Extension, as it has been mineralized with an ore shoot that is known in the Extension mine as the Mizpah vein. The horizontal shift of the contact between the Mizpah and Mizpah trachyte along this fault amounts to about 1,000 feet on the 1,540-foot level of the Tonopah Extension, and as the contact dips about 45° in that place, the movement along the fault must have been the same. Along this vein on the 1,540-foot level, south of the McKane shaft, it is clear that the fault is compound, consisting of two major branches, which in places must be

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200 feet apart. To the west, however, they appear to join. The workings on the 800-foot level of the West End Extension and Tonopah 76 mines do not show a similar branching, unless the two masses of quartz found in the workings south of the main crosscut, or "Long Shot," represent the western junction of the branches.

The second of the two faults in this group may be called the Monarch-Pittsburg fault, as it has been rather extensively explored in the mine of that name, where it appears to have been mineralized. It has also been exposed on the 800-foot and 960-foot levels of the West End mine, where it cuts off the Ohio vein, and in the lower levels of the Tonopah Extension mine where it offsets the Murray vein. The fault is essentially continuous between the exposures in the Extension and those in the Monarch-Pittsburg, but is cut and displaced by two large younger faults in the region between the Monarch-Pittsburg and the West End. The offset of the Murray vein in the Tonopah Extension mine indicates that the vertical movement along this fault must amount to about 1,000 feet. The Monarch-Pittsburg fault, like the parallel fault to the west, is compound, two major branches, which unite both to the southeast and to the northwest, being observed in the more westerly workings. In the Tonopah Extension mine this fault is known as the Denver fault.

Only one fault was recognized that may be placed in the second group. This fault, which is known in the Extension mine as the Rainbow fault, has a northerly to northeasterly strike and an easterly dip. It is best exposed on the 600-foot level, about midway between the Extension No. 1 and San Grass shafts. In most of these exposures the strike is nearly north, but southward toward the 600-foot level of the McNamara mine the fault splits, and the main branch assumes a northeasterly strike. The workings on the Ohio vein, particularly on the 555-foot level, show that this southeasterly branch is cut and offset by the Extension fault of the third group. The vertical movement along the fault is about 150 feet in the lower levels of the mine. On the upper levels the throw decreases and is divided between several branches; the movement along the main southwesterly branch was about 50 feet.

The third group of faults has a northerly strike and a steep westward dip. The throw along them is relatively small compared to that along the faults of the first group. The most thoroughly developed fault in the group is the Extension fault, which has been exposed throughout the vertical range of the

ension workings and is also shown in parts of
 ara and West End mines. On the lower levels
 sion mine the vertical movement along the fault
 about 125 feet, but on the upper levels it appears
 somewhat less, in part at least because of the devel-
 opment of several branches.

Western fault of this group is the 76 fault, exposed
 Extension and in the West End Extension and Tono-
 where it offsets the Merton vein. The vertical
 somewhat less than 100 feet. Another fault of this
 ent near the McKane shaft, where it offsets the
 ch-Pittsburg fault. It may be called the McKane
 vertical movement along it is about 150 feet just
 0-foot level but appears to decrease rapidly upward,
 about 50 feet in the Monarch-Pittsburg workings.
 gs were not accessible, and it is not clear if this
 row is the result of branching upward, as in the
 it.

A different behavior is exhibited by the fault to the
 ult, which is unnamed, is about halfway between
 nd Extension faults and is exposed in the workings
 sion No. 2 shaft and the Extension incline. The
 placement along the fault in this vicinity appears
 about at the 1,260-foot level, where the Murray
 dropped on the hanging-wall side about 100 feet
 low this level the fault passes into a flexure, as is
 curving hanging wall of the Murray vein on the
 l. Above the 1,260-foot level the throw decreases,
 50-foot level is comparatively insignificant. This
 to be represented to the south by a fault of similar
 that is exposed in two places on the 800-foot level
 shaft. Here, however, the throw is considerably
 e offsetting of the Monarch-Pittsburg fault by it
 vertical drop of at least 200 feet.

ult of the third group that need be considered here
 n the western part of the property of the Tonopah
 hich has been called the Buried fault. This fault
 of the upper branch of the Tonopah fault and drops
 slightly more than 100 feet. The workings from
 g Boy shaft indicate that it frays out southward
 and as it could not be recognized in the Midway
 ust also die out northward. It is not certain that
 of the same age as the other faults in this group,

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for it appears to offset minor faults of similar strike to the that have been placed in the fourth group.

The faults of the fourth group strike northeast to east-northeast and dip at different angles to the southeast. The most interesting fault of this group is one that has been called the MacNamara fault in the mine of that name. This fault is well exposed in the upper levels of the MacNamara and Wagon Wheel End mines, where it displaces the upper branch of the Tonopah fault and may be correlated with a fair degree of certainty with a fault of similar strike and dip that cuts the Ohio vein on the 700-foot level of the MacNamara and 800-foot level of the Wagon Wheel End. On the latter level the fault is clearly later than the Extension, Rainbow, and Monarch-Pittsburg faults. In this region the vertical displacement along the fault ranges from more than 200 feet on the western portion of the 800-foot level of the Ohio vein to less than 50 feet where it cuts the Tonopah fault on the 500-foot level of the Tonopah Mining Co. East of the latter point, however, the character of the fault appears to change completely near the hanging wall of the older Tonopah fault. The displacement decreases notably, and the fault takes on a rolling habit which appears to be partly controlled by the low eastward pitch of the nose of the Tonopah fault. This is well exhibited on the more westerly workings of the 600-foot level from the Mizpah shaft and on the 530-foot level of the Midway. The displacement along this rolling portion of the fault is considerably greater than that shown by the offsetting of the Tonopah fault to the west. This feature appears to be most readily explained by considering that the excess movement along this portion of the MacNamara fault is represented elsewhere by renewed movement along the upper branch of the Tonopah fault, which roughly corresponds to it in strike and dip.

The fact that the MacNamara fault resumes its normal character upward away from the Tonopah fault is shown by the workings north of the shaft on the 500-foot level of the Roubidoux Plume mine.

Another major fault in this group is the Sand Grass fault which is well exposed only on the 600-foot level of the Sand Grass mine, where it cuts the shaft, and on the 660-foot level of the Tonopah Extension mine. It is thought that exposures of faults with similar strike and dip on the 1,050-foot and 770-foot levels from the Extension No. 1 shaft and the 1,000-foot level of the Ohio represent the same fault; and others on the 600-foot

Monarch-Pittsburg and the 800-foot level of the Extension-Tonopah 76 just west of the Monarch-Extension are still more western extensions. To the west the Tonopah fault is dropped more than 150 feet vertically on the 660-foot level of the Extension-Tonopah 76, but on the 660-foot level of the Extension-Tonopah 76 the fault is distributed along several branches.

Other faults of similar strike and dip are exposed in the Extension-Tonopah 76. The faults of the Tonopah Mining Co., Jim Butler, and West Extension-Tonopah 76 are relatively small. One of the largest is the Silver Top fault, in the ground of the Tonopah Mining Co., which offsets the Valley View vein through-

out along the faults of all these four groups must have been accomplished before the deposition of the ore, since unshattered quartz has been deposited in places along all of them. In some of these occurrences such as the Silver Top fault, the quartz is continuous with the quartz of the mineralized Tonopah Extension-Tonopah 76 fault veins. In addition ore has been stoped along the faults, as on the Merton vein in the Tonopah Extension-Tonopah 76 and on the Rainier-MacNamara. There has of course been post-deposition movement along some of the faults, for in several places the faults are present in the fault gouge, but this movement has been relatively slight.

THE ORE BODIES

The character of the silver-rich ore bodies have been described by Spurr¹ and by Bastin and Laney.² The descriptions from the latter authors rather inadequately summarize their conclusions regarding the ores:

By Spurr, the ores of Tonopah are in the main replacement zones of fracturing. They are therefore ore-bearing veins. Every gradation may be traced from heavy breccias to slightly replaced wall rock. Ore-cemented breccias, conchoidal structure, and other features characteristic of replacement zones are rare or developed only on a small scale. Somewhat resembling true crustification, which is characteristic of replacement zones, is possibly to be explained by diffusion during

hypogene mineralization has played an interesting part in the formation of the Tonopah ores, it appears to have been much less important than the hypogene mineralization.

¹ U. S. Geol. Survey Prof. Paper 42, pp. 83-96, 115-207, 1905.
² Bastin and Laney, F. B., U. S. Geol. Survey Prof. Paper 104, 1918.

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Most of the ore bodies in which it was most prominent are worked out and the principal dependence of the mines today is upon ores that, the writers believe, are almost wholly of hypogene origin.¹

In view of the adequate description of the character of the ores given in these two publications, it seems desirable in this preliminary report to consider only the factors that are thought to have been active in the localization of the ore bodies. A complete discussion of this subject, however, is not possible, for it would require the use of physico-chemical data that are only partly known. The following paragraphs, in which the factors derived empirically from a study of the known ore bodies are considered, may nevertheless prove of some benefit in directing future exploration.

The most outstanding feature of the known ore bodies in the western part of the district is their localization in the Tonopah fault and its subsidiary fractures. There is, of course, no direct connection between the ore and the fault, because extensive faulting intervened between the formation of the Tonopah fault and the deposition of the ore, and the later faults are only locally mineralized. It would seem rather that at the time the silver mineralization occurred the nearly east-west Tonopah fault and its associated fractures were parallel to compressive forces existing at that time, and they therefore were capable of being open to the mineralizing solutions. Applying this conclusion to future exploration would suggest that, subject to the limitations imposed by the other factors, development work should be confined to the Tonopah fault and its branches and splits, almost all of which are found on the hanging wall, and to such other fractures or faults as have a parallel strike. The fractures that radiate from the crest of the upper branch of the main fault appear to have been rather thoroughly explored, but this cannot be said for those that radiate from the crest of the lower branch. One such fracture has been found to be ore bearing in the West End mine, and it is possible that other similar ones may be present.

Ore bodies are unfortunately not found everywhere along the Tonopah fault and its branches; and there obviously must be additional factors governing their local distribution. The writer believes that the most essential requisites for the deposition of ore along these fractures were, first, that they should be open to the flow of the ore solutions at the time the solutions were circulating, and second, that the wall rock along such open fractures should be of a nature to facilitate precipitation and accumulation of the silver minerals.

¹stin, E. S., and Laney, F. B., op. cit., pp. 9-10.

these two requisites at first may seem unnecessary. It was shown above that the Tonopah fault in all the path along which the ore solutions circulated, was open. However, in many places along the Tonopah fault are large masses of quartz in which the silver is too low to be minable, and in other places, particularly in the wall branches of the Tonopah fault, there are large masses of ore of rather high grade in which quartz is absent. These two features suggest strongly that the ore deposition was in large part independent of the introduction of the quartz found in the veins. Examination of the specimens confirms this belief, for it shows that the ore and those associated with them are distinctly later than the quartz. It is therefore plain that in many places the fault could have been effectually sealed to the passage of mineralizing solutions by the introduction of essentially impermeable quartz and that renewed, postquartz movement was essential to the formation of an ore body.

In places along the fault, however, there are no quartz bodies. In others there are quartz bodies with well-defined boundaries. In some of these types of occurrence there should have been freedom for the passage of solutions if freedom for the passage of solutions was the only requirement. Both, however, are locally barred. The quartz probably may be attributed to the fact that at these places was of such a character that it was highly impermeable gougy material adjacent to the fault. This condition contrasts with the conditions existing in the foot walls, where the rock is of such a nature that both the quartz and the ore were fractured to form a readily permeable material. With respect to this character, the rock may be referred to as nonbrittle or brittle, the latter being the more common type. The brittleness cannot be directly correlated with the different formations described, but is rather a result of the kind of alteration they have undergone. Thus, in the case of the Tonopah Mining Co., the Mizpah trachyte was altered to a hard brittle white rock composed largely of microcline and quartz, and forms the wall rock of numerous mines. Farther west, however, chloritic alteration has transformed the rock to a relatively plastic or nonbrittle rock in which ore deposits are relatively scarce. Contrary to the West End rhyolite in the Tonopah Mining District is soft and unfavorable for ore deposition, and the Tonopah Extension and West End mines extensive

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silicification has converted it into material that has afforded ample fractures for admission of the ore-depositing solutions.

The determination as to the direction of exploration based upon these two factors is a somewhat more difficult matter than that based upon the relation of ore to the Tonopah fault. It appears to the writer that the character of the wall rock is by far the more important of the two in relation to possible ore deposits, in that if this condition is satisfied along a known fracture it is probable that the fracture will be found to have been open to ore-bearing solutions at some place along its strike or dip. Prediction as to the character of the wall rock must necessarily be based upon the observed alteration. At present it is not possible to delimit areas in which favorable rock may be expected to occur, but from the work thus far accomplished it seems probable that this may be done when the field work has been completed.

The final factor—that of depth—demands recognition, but the data available are not sufficient to determine its true importance. The fact that some of the ore bodies decrease in value with depth has been noted by Bastin and Laney,¹ and in similar occurrences seen by the writer the decreased silver content does not appear to be explained by the action of any of the three factors above set forth. In such occurrences the appearance of the vein material is not greatly changed, except that the sulphides present are almost entirely those of the base metals, silver sulphides occurring only sparingly. It is impossible to set a definite elevation at which this decrease may be expected to be operative, for the few localities at which it is thought to have occurred vary considerably among themselves; for example, the inadequate information now available appears to show that this depth may be different on either side of a premineral fault. The writer believes that these features may best be explained by considering that the depth of ore deposition was also controlled by the temperature of the ore-depositing solutions, in that above a certain temperature the precipitation of silver sulphides was impeded; and that at different localities this temperature was reached by the cooling, ascending solutions at different elevations, because of differences in the facilities for movement of the solutions along the ore channels. In general, it seems to be true that the required elevation was higher in the central part of the district than it was in the western part, but this statement is subject to many local variations.

¹Bastin, E. S., and Laney, F. B., op. cit., p. 44.

CONCLUSIONS

The relations that have been disclosed by the resurvey in this district would appear to warrant continued exploration if economic conditions are favorable. The work indicates that ore deposition occurred relatively late in the geologic history, and that, as a result, ore may be found in various formations rather than being limited to one. If this conclusion is based upon the several factors that appear to control ore deposition, it seems probable that such areas will be rewarded by new discoveries of ore.

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No. 3

UNIVERSITY OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

STUDIES ON ORE DEPOSITS AT CAVE
PAULLEY, PATTERSON DISTRICT,
LINCOLN COUNTY, NEVADA

By F. C. SCHRADER
Geologist, U. S. Geological Survey

DESIGNED AND PUBLISHED BY THE NEVADA STATE BUREAU OF MINES
IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY



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DEPOSITS AT CAVE VALLEY, PATTERSON DISTRICT, LINCOLN COUNTY, NEVADA¹

By F. C. SCHRADER

INTRODUCTION

Cave Valley that formed the basis of this report was discovered in the summer of 1930 by a request from the Joint Committee on Appropriations of the House of Representatives to the Geological Survey for an investigation of uranium deposits. The deposits at Cave Valley had recently been found to contain uranium, which is the source of radium, and the examination was therefore delegated to examine them; but the results of the examination were negative. Small shoots of silver have been mined in this locality, and the outlook for the future depends principally upon conditions that would favor the occurrence of similar ore bodies.

For the many valuable pieces of information received, thanks are due to the management of the Great Western Mining & Development Co., and to Mr. Claude Morris, without whose aid in the field work this report would not have been available.

LOCATION

Cave Valley is in the Patterson (Geyser) district, about 10 miles south of Ely and 45 miles north of Pioche, which are the nearest railroad stations. It covers the south end of the Snake Range, which here is high and narrow and separates Cave Valley on the east from Cave Valley on the west. The valley stands at an elevation of about 7,250 feet, and is about 6 miles north of the pass, at 10,000 feet, or above the adjacent valleys. The principal supply point is reached by a good road along the long, narrow

EARLY DEVELOPMENTS

The Patterson district has been described more fully by Hill² and chiefly by Lincoln,³ according to whom the country consists of Cambrian quartzite, limestone, and shale, which

¹ By permission of the Director, U. S. Geological Survey.
² Notes on some mining districts in eastern Nevada; U. S. Geol. Surv., pp. 120-124, 1916.
³ Mining districts and mineral resources of Nevada, pp. 123-124.

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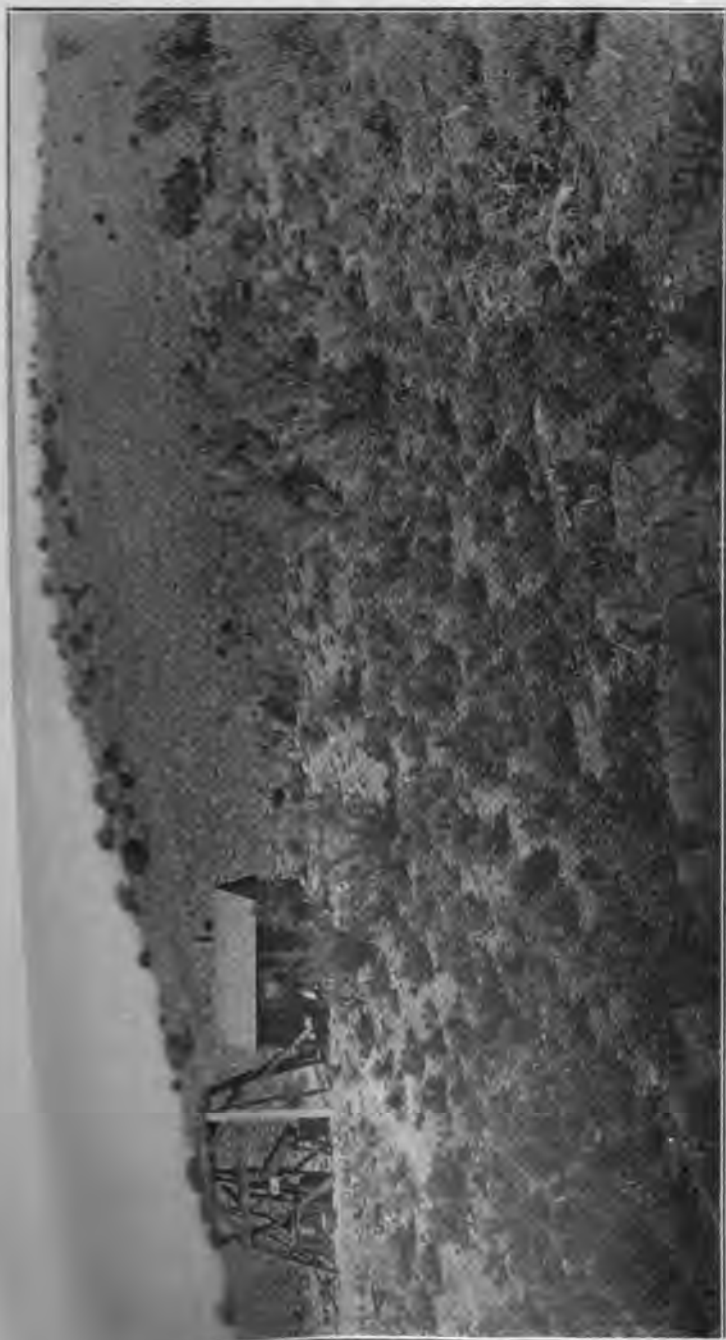


Fig. 1. Photograph showing Cave Valley Mine, Topography and Limestone Formation. Looking Northwest.

faulted and have a total thickness of several thousand feet. They dip steeply east for the most part. The only notable feature is a dike of granite porphyry, which is 50 feet thick and runs northwest across the crest of the range at the Swartz Canyon, three miles north of the pass.

Mineral shows were found in the north side of Patterson Pass. Soon thereafter more than 200 claims were staked, mostly in Swartz Canyon, and a mill was built. About 1880 water showings of mineral were also found at and near Cave Spring, on the west side of Cave Valley, six miles north of the pass.

The geology of the district consisted chiefly of small replacement veins of well-crystallized quartz and calcite, mostly in the shale, accompanied by minerals containing lead, antimony, and arsenic in moderate quantity. A few thin films of pyrite, lead carbonate and more numerous small pockets of malachite and copper carbonates were of most interest, but they were soon exhausted, and the district was abandoned at the close of the early-day production.

The work was done on the Robertson property, near the crest of the range on its west side three miles north of Cave Spring. Here the showing consisted mainly of crushed and malachite coated with copper carbonate. At the Swartz Canyon, on the summit of the range at Swartz Canyon, which was worked at that time, films of sphalerite and pyrite, arsenic-bearing planes, and a little molybdenite occur in shale which is metamorphosed and resembles greenstone.

In 1921 the Lake Valley Mining Co. shipped some silver bullion and began building a 50-ton cyanide plant, in 1922-1925 it produced some silver bullion.

From 1926 to 1930 some work was done on the Cave group, at Cave Spring. In the Streater group, three miles northwest of the Cave group, the two properties are described in some detail in the following pages.

DETAILED DESCRIPTIONS

CAVE GROUP

The Cave group of claims, owned by the Great Western Mining Co., is in Cave Valley just north of Cave Spring. It covers the west foothill slope of the Shell Creek Range at an elevation of about 6,700 feet. It lies for the most part on a gentle rolling surface, which declines gently westward to the valley. A portion of it is shown in Figure 1.

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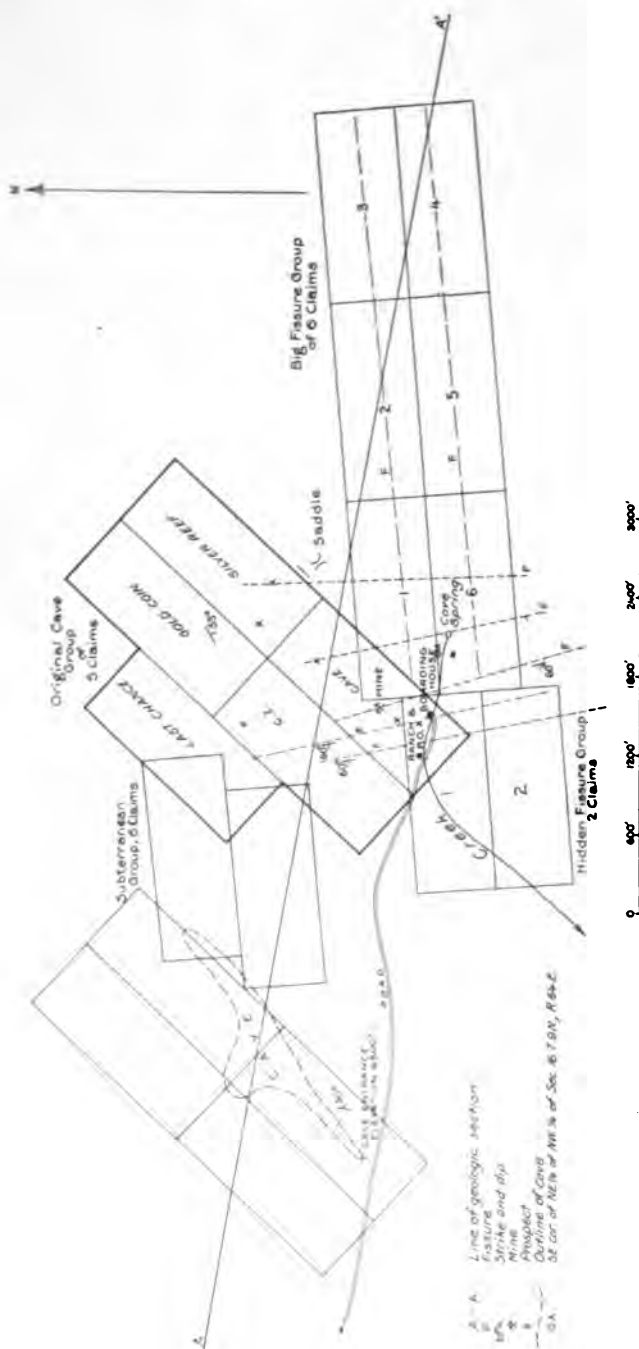


Fig. 2. Sketch Map of Cave Valley Group of Claims.

History and Production

group comprises 21 claims, the nucleus and most of which is the original group of five claims, the heavy border line in Figure 2. These five claims were patented in 1921 by John C. Clark and J. C. Riordon, although different persons had tried unsuccessfully to work them for some time.

The Ely-Pioche Amalgamated Lead-Silver Mines Company worked on them, and in 1926 they were acquired by the Nevada Mining & Development Co., which has since been working them intermittently on a small scale and has added to the original group. According to Mr. Clark, some lead has been mined and shipped during the period of Clark-Ely-Pioche ownership. A lot of oxidized lead ore during development work was shipped by the Ely-Pioche

company. Production has been reported except a few test shipments of ore, about five tons each, and a fair quantity of lead that remains on the dump at the mine.

The workings extend to a maximum depth of 120 feet, as shown in Figure 2. The mine is equipped with a 50-horsepower 8-ton steam engine, air compressor, and buildings to accommodate a crew of 10 men. The camp is supplied with excellent water from a well which issues in a strong stream from a fissure at the base of a limestone cliff 30 feet high at the upper edge of the dump.

Geology

The rocks in Cave Valley are chiefly Cambrian quartzite, sandstone, and shale, similar to those at Patterson, and are a part of the same series. Their relations and attitudes are indicated in the section, Figure 4. In general they dip to the west, or diagonally into the Shell Creek Range, at angles of 10° to 20°. This attitude is similar to that of the rocks at Patterson and suggests that the Shell Creek Range in this area is essentially monoclinical, with easterly dip. The apparent thickness of the rocks may involve considerable duplication. They have been much crushed and faulted. Several faults are shown near the middle part of the section, as indicated in Figure 4.

The fissures trend north and dip steeply to the west, and are common in the range. On the Big Fissure group the two cross

Clark, *Mineral Resources*, part 1, p. 685, 1925.

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fissures stand about vertical. The south one makes the best mineral showing.

The limestones are mostly bluish-gray and blue, more or less crystalline, and medium to thick bedded. The shales occur chiefly as dark intercalated thin beds.

Near the middle part of the section there is a bed of micaceous shale about 100 feet thick. (See Figure 4.) It is lead-gray to iron-gray, dense, closely but dimly banded, more or less finely pyritic, and on weathered joint planes is banded by yellowish brown limonite streaks one-tenth of an inch or more wide. Locally, especially in the southern part of the Cave Valley mine, it has a pronounced laminated structure. The microscope shows it to be composed of very fine grained quartz, sericite, and secondary calcite, with considerable disseminated pyrite and detrital garnet. It seems to be peculiarly susceptible to mineralization. The veins of the Cave Valley mine and other prospects occur in it.

The chief ground for referring the rocks to the Cambrian system consists of fossil remains which were found in the present work near the Cave Valley mine and the middle part of the section, in the limestone above the quartzite, and which Mr. Edward Kirk, paleontologist, of the United States Geological Survey, has determined to be algæ of Cambrian age. The stratigraphic position of the fossil-bearing limestone seems to be the same as that existing near Patterson, where F. B. Weeks collected Cambrian fossils in limestone that overlies the quartzite.¹

The deposits consist of replacement bodies along fissures in the limestone and quartzite. The replacement veins along fissures are shown in Figures 2 and 4. The bodies that have replaced certain beds of limestone are as much as two feet in thickness and are regarded as favorable features. They are mostly associated with fissures, but some of them occur independently, as shown in open pits north of the mine.

Cave Valley Mine

The principal replacement vein is that of the Cave Valley mine, which is opened to a depth of 120 feet and has been followed by 500 feet of drifts, as shown in Figure 3. It strikes north-northwest and dips 80° WSW. in the gray micaceous shale which dips 45° SE.

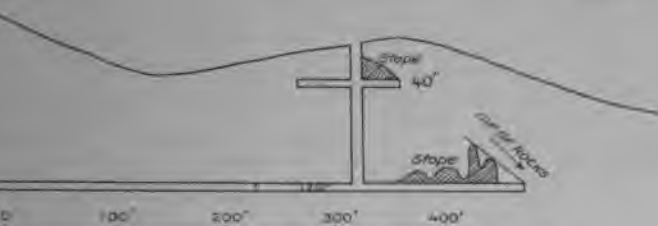
Ore is said to have been followed from the outcrop nearly the way down the shaft, and good ore was mined from shaft

¹Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, p. 40, 1903.

40-foot level. Most of the ore produced, however, is from the south drift and stopes on the 120-foot level. The ore seems to be continuous throughout on the 120-foot level. A layer of several inches thick is exposed at each end of the vein, especially at the south end; but its thickness on the whole varies ranging from an inch to about five feet. The vein contains extensive lenses, which in places contain only barren rock or finely crushed rock. In some places the ore is irregularly banded and streaked.

The ore is siliceous lead-silver-copper with a trace of gold. The host rock is mainly silicified limestone. One test shipment of $4\frac{1}{2}$ tons at the present owners is reported to have been valued at \$94 a ton, but the small quantity for a period of several years imply that the quantity

S. 10 E.



Longitudinal Section of Cave Valley Mine. Looking East on Hanging Wall Side of Vein.

There is not much ore in any continuous body is not great. There is not much ore of milling grade.

The ore is stained green with malachite or brownish with lead carbonate, and some of it contains spots of a dull black substance, which may be "copper pitch ore" in occurrence but seems to be due to the silver and lead of the ore. Examinations made by the United States Geological Survey, indicate that the material is mainly an undetermined oxidized mineral or minerals containing arsenic, lead, and a little copper. The mineral is siliceous and translucent and gives a light-brown powder when powdered. In polarized reflected light it is isotropic, which indicates that it is amorphous. It contains also microcrystals of a silvery white metallic mineral which proves to be a sulphide of silver and arsenic ($9Ag_2S.As_2S_3$), and is most completely replaced by the black mineral. The

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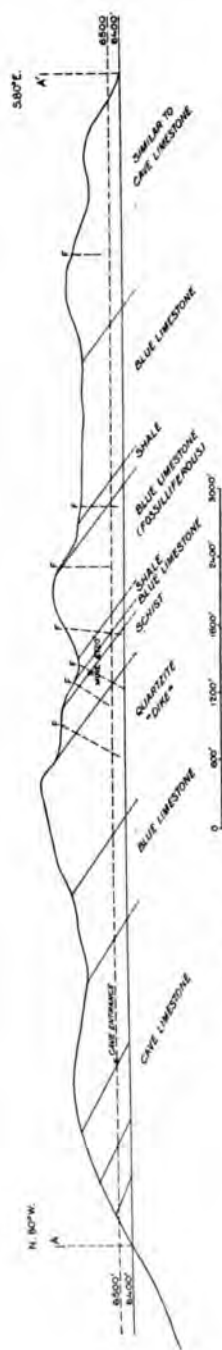


Fig. 4. Diagrammatic Geologic Section at Cave Valley.

however, is regarded as primary and the chief source of the content of the ore. The trace of gold contained in the ore is probably associated with the pearcrite and its oxidation. Silver is probably present also as horn silver or cerargyrite in some other oxidized mineral derived from pearcrite and is contained in the lead carbonate.

A section from the face of the north drift on the 120-foot level shows that the ore there has essentially a gangue of dimly crystalline quartz. The quartz occurs mostly in elongated forms with regular or ragged terminations and borders and exhibits a gratelike structure. Other constituents of the vein are thin plates of sericite, seemingly derived from argillaceous material in the replaced rock, and considerable secondary calcite, which occurs (a) interstitially in the quartz, (b) as veinlets and (c) as minute, slightly greenish rhombs scattered throughout the section. Pyrite is present in small amount, as small, dull black mineral with pearcrite inclusions, which occurs in regular spots and in seams or veinlets and is associated with calcite. Here and there, especially on fractures and fractures, the ore is coated or stained with a green powdery finely crystalline mineral. This was thought to be uranium oxide or carnotite, but it has not been identified in the present work as psittacinite, a lead-copper vanadate ($2\text{PbO} \cdot 2\text{CuO} \cdot \text{V}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$) containing uranium, lead, and copper and a trace of zinc. As the presence of uranium and radium had been reported, however, representative ore specimens were collected from well-exposed parts of the Cave Valley deposits and were tested for radioactivity by the radiograph method. Six of the specimens were from the Cave Valley group property and included one specimen from a deposit in the cave. The seventh was from the group of claims. Photographic plates were exposed to the specimens for periods of one to ten days, without giving any indication of radioactivity. Chemical tests of the ore also failed to detect the presence of uranium oxide or any radium-bearing mineral.

Clay in Cave Valley Cave

The cave from which the valley takes its name is covered by a pre-Cambrian claim group, shown at the left in Figure 2. Unlike the stalactites and stalagmites that are found in many limestone caverns, this cave has long been visited and of interest by people of the surrounding region. It is accessible, the entrance being nearly on a level with the top of the foot of the limestone ridge. The cave is said to extend

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northeastward beneath the ridge for 2,300 feet and to have a maximum width of about 600 feet. Its floor is nearly horizontal and its ceiling in general stands six feet or more above the floor.

A possible economic feature of the cave is a clay deposit that forms the floor for a distance of at least 1,500 feet from the portal and perhaps for the full length. This deposit has a maximum thickness of 40 feet or more. The clay has recently been explored by the present owners to a depth of ten feet without reaching bottom, and a prospect shaft is said to have been sunk by Mr. Robinson to a depth of 40 feet without reaching bottom. Mr. Robinson reported that he found silver in the clay in the shaft but not enough to encourage further prospecting. The clay so far as seen by the present writer is stained a decided red color by iron oxide, but it is said to become yellowish in the deeper parts of the cave.

The clay is slightly streaked or laminated. It is very homogeneous, free from grit of any kind, and smooth or talcose to the feel. A partial analysis made for the owners by Crismon Nichols indicated 27.8 per cent aluminum oxide, 0.4 ounces silver to the ton, small quantities of iron, phosphorus, lime, magnesium, and silica, and traces of gold, copper, arsenic, antimony, and vanadium. It also showed 0.251 per cent of uranium oxide, but a specimen of the clay collected by the writer from a pit 8 feet deep at 600 feet in from the portal of the cave showed no trace of radioactive activity in the radiograph test.

The deposit is estimated to contain about 200,000 cubic yards of clay, but the red color of its upper part and the yellow color of the remainder imply that the iron content is too high to adapt the clay for high-grade uses, and costs of transportation to centers of consumption afford no hope for its development at present.

STREATOR GROUP

The Streator group, which is also owned by the Great Western Mining & Development Co., is situated in the foothills about three miles northwest of Cave Valley, at an elevation of about 7,000 feet, and is easy of access. The hills here support a moderate growth of cedar, juniper, and pinon.

The property comprises a group of five claims known as the Consolidated group. (See Figure 5.) It is reported to have produced some high-grade shipping ore at a relatively early date. About 90 tons of mill ore lay on the mine dump at the time of the visit. Considerable work is said to have been done in 1929, and some in shallow openings was done as late as June, 1930.

erty is developed at several points by shallow openings, of which, known as the Streator mine or shaft, is on the No. 1 claim and has a depth of 60 feet.

The rocks are blue limestone, quartzite, and schist, which are continuations of those at Cave Valley, though here they seem to be lighter in color. They dip about 30° here, as at Cave Valley and Patterson, the mineral content in the limestone and schist above the quartzite. They contain lead, silver, and copper and are very similar to those at Cave Valley in general occurrence, appearance, and

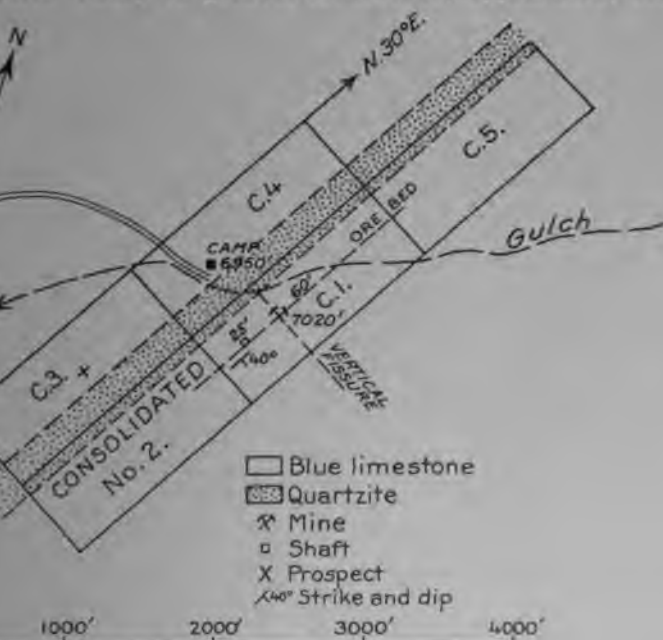


Fig. 5. Sketch Map of Streator Claims.

position, but the psittacinite stains are here more numerous and some of them have a pronounced canary-yellow color. These occur mostly as replacement deposits in silicified limestone, a gangue of quartz, barite, and altered rock. The mineral is argentiferous galena, but spots of the duller mineral with pearcite inclusions as much as three-tenths of an inch in diameter are also present. Some of the ore consists of silicified limestone, stained by yellowish-brown iron oxides and lead and copper carbonates. It is crudely ribbed with stringers of replacement quartz as much as two inches wide, which are associated in places with smaller

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stringers and irregular spots of fine-grained galena and the black mineral.

The principal deposit is the replaced limestone bed intersected by a cross fissure at the 60-foot shaft. Here good ore is shown in the cross fissure, opened to depths of ten feet or more on the northwest or footwall side of the ore bed. In the upper part of the workings the ore body is exposed for a width of $2\frac{1}{2}$ feet. It parallels the limestone in strike but dips more steeply and may pass into the underlying shale in depth. Probable continuations of the same ore zone are opened by shallow shafts at points about 100 feet northeast and 350 feet southwest of the mine, and both openings are encouraging. The ore in this zone is mostly stained brown and shows less galena and less pyrite stain than the ore along fissures, but this difference may be due to a greater degree of oxidation along the replaced bed. The deposits collectively are believed to contain a fair quantity of mill-grade ore.

EAGLE ROCK GROUP

Up in the range east of Cave Valley, just below a pair of peaks called the "horns," John C. Clark and Francis Riordon are developing two quartz veins on the Eagle Rock group. The veins are in silicified limestone and are said to contain tungsten ore to assays \$5 to the ton in gold and "appreciable" amounts of silver. Two specimens were collected from the veins for the writer. One of them, said to be from the Eagle Rock division, contains no tungsten. It consists chiefly of vein quartz, which is somewhat brecciated and contains irregular spots of dark-gray or blackish cerussite with disseminated specks of residual galena. Some of the cerussite occurs also in the wall rock associated more or less with quartz stringers. Associated with the cerussite is a yellowish lead-antimony mineral, probably bismuthinite, which stains the surrounding quartz or occurs in veinlets and stringers. It seems to be a secondary oxidation product derived from cerussite. The quartz is also traversed by stringers and veinlets of secondary calcite.

The other specimen, from the vein on Eagle Rock No. 2 division, consists chiefly of vein quartz, in part stained reddish-brown by iron oxide and slightly porous or honeycombed by cavities from which it has a porous feel. It contains considerable quantities of the form of cerussite, a black submetallic mineral that occurs in small, irregular crystals and laminae, usually less than 1/16 inch in diameter.

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UNIVERSITY OF NEVADA BULLETIN

AUGUST 1, 1931

No. 5

UNIVERSITY OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

DEPOSITS OF THE GOLD BATTLE MOUNTAIN DISTRICT, WYOMING COUNTY, NEVADA

By EDWARD H. ROTT, Jr.

Assistant Geologist, Consolidated Coppermines
Corporation, Kimberly, Nevada



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1931

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FOREWORD

ulletin is a thesis, with some additions thereto, submitted
ott for the degree of Master of Arts at the University
nia.

olicy of the Bureau of Mines is to publish pertinent
on regarding Nevada mining districts. This paper
h a district which has not heretofore received any
nsive petrographic study of its ores or country rocks,
efore the first scientific geologic treatise in detail on
et.

JOHN A. FULTON,
Director.

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GOLD DEPOSITS OF THE GOLD CIRCLE MINING DISTRICT, NEVADA

By Edward H. Rott, Jr.

INTRODUCTION

FIELD AND LABORATORY WORK

This report is based on work done in the Gold Circle mining district during the summer of 1927 and during brief visits to the district in June, 1928, and April, 1929. The field work was supplemented by laboratory study of the specimens collected in the district at the University of California during the fall and winter semesters of 1927 and 1928, and by a brief review of the work done in the geologic laboratory of Consolidated Coppermines at Kimberly, Nevada, in the fall of 1930. A considerable part of the district was studied in detail, and a geological map prepared (Plate I). Detailed underground geology was done on the 300 level of the Elko Prince and Jackson veins, in the Grant and Jackson mine, in the Reco tunnel, and in the Rex tunnel. Other workings in the district were examined for the general character of the veins, wall rocks, associated rocks, and faulting.

ACKNOWLEDGMENTS

The author is sincerely grateful to the staff of the Gold Circle Mining District, especially to Senator Noble H. Getchell, general manager, who made this work possible. Dr. George D. Louder and Dr. Carlton D. Hulin have given invaluable advice, criticism, and encouragement during the progress of this work at the University of California.

LOCATION OF THE DISTRICT

The Gold Circle, also known as Midas District, is in the northcentral part of Nevada just east of the west boundary of Elko County. It is located about forty-five miles north of Battle Mountain, and fifty miles east of Golconda, towns on the Southern Pacific Railroad (see Plate 1). Tuscarora, a thriving camp from 1872 until 1900, is about thirty-five miles east. Red House, a station on the Southern Pacific Railroad, is about thirty-five miles southwest. The mines are operated on alternate days, except Sundays, from Golconda and Battle Mountain.

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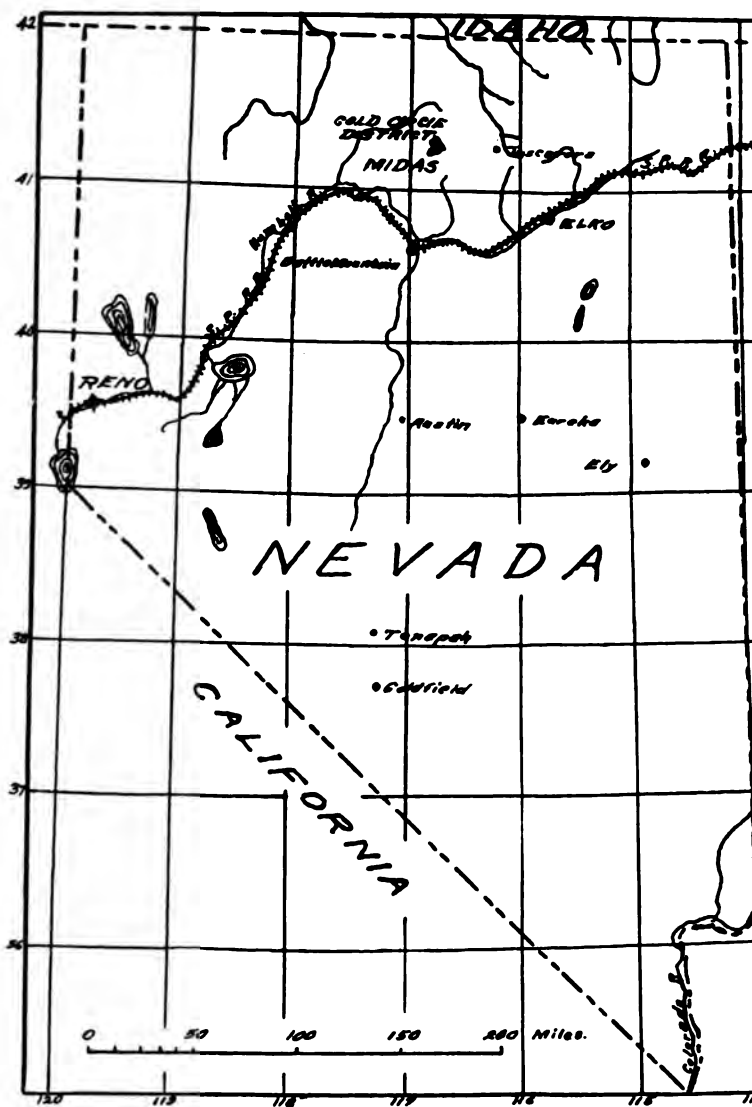


FIGURE 1
Index Map of Nevada Showing the Location of Gold Circle District
(Revised from U. S. G. S. Bulletin 408.)

TOPOGRAPHY

lies in the hilly country along the southeast slope of the Bluffs, between the bluffs and Squaw Valley. The elevation gradually increases in elevation from south to north, from the bluffs to the north and northeast. In the vicinity of this work the maximum relief is about 1,000 feet. In the immediate vicinity of Midas the bluffs are sharply rising from the hilly country, and swing to the west, south of the hill area.

HISTORY OF THE DISTRICT

was discovered in the summer of 1907 and by March, 1908, the district was booming. The first excitement soon subsided and the population increased in population to over 1,500 people during the summer, but by September it had shrunk to a settlement of 250 by September.

Several companies were organized to operate the mines in the district, and in all six or more mills, ranging in capacity from five to seventy-five tons per day, were built and operated during the life of the camp. The operations of the Prince Mining Company and the Gold Circle Consolidated were the most extensive in the district.

The Prince mine was located in 1907 and taken over by the Prince Mining Company in 1908. By agreement with the Prince company, a fifty-ton cyanide mill was erected at the mine and operated until 1922, when the mill burned. After the mill burned the company ceased operation. By 1922 the most promising holdings in the district had been acquired by the Gold Circle Consolidated Mines. Mining operations were begun and a seventy-five ton cyanide mill constructed at the Gold Circle Consolidated Mines. Treatment of ore began in the spring of 1927 and operations continued until 1929. The principal production during this period was from the Grant-Jackson vein above the 225 level, and from the Pink vein. From the latter part of 1928 until the mill burned in the fall of 1929, some production came from the Pink vein above the 600 level, principally from the 450 level and the 300 level on the June Bell vein.

After reorganization, the Gold Circle Consolidated Mines acquired the Betty O'Neal Mines in Nevada, and its holdings. The company has started to dewater the Elko shaft to the 900 foot level, and plan to sink the shaft to the 1,000 foot level. Development on the other holdings will be continued. The leasers are working in the district, and through

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Andesite rhyolites, occurs in both the east and Elko Prince vein at the surface, and in the east on the 300 level. This rhyolite is moderately light gray in color. It is compact with a few small vesicles. The groundmass is glassy material. The rock contains phenocrysts of fine feldspar, quartz, and a notable amount of crystals. What appears to be tuffaceous material is in the formation.

The rhyolite is in contact with the andesite under the surface. The underground contact indicates that the flows is conformably overlain by the andesite. The rhyolite has not been differentiated from the post-Elko and the June Bell rhyolite in the major portion

ANDESITE

Following the Elko Prince rhyolite, andesite with some salt and diabase flows was poured forth on the rhyolite. The parts of the contact that were underground workings gave no indications of an erosion between the rhyolite and the andesite. The andesite flows occur in the southeast, southwest, and north of the area mapped, with some irregular masses and within the rhyolite area.

The andesite varies considerably in appearance, but in a general description it may be designated as a greenish-brown, porphyritic rock, with feldspar and pyroxene in a matrix of undifferentiated constituents. Under the microscope the feldspar was seen to be acid andesine, and the pyroxene to be augite. The feldspars are partly altered to calcite, and the pyroxene to calcite and chlorite. In the rock is fine-grained, with lath shaped phenocrysts of andesine and augite in an altered groundmass of glass, chlorite and calcite.

The specimen contained phenocrysts of basic andesine and groundmass composed principally of brown glass, with laths (about acid andesine), minute prisms of magnetite, and very large crystals of magnetite and intensely altered composed of serpentine, calcite, and iron oxide. Fragments and remnants of biotite occur, also amygdules of chalcedonic silica.

The rock is a black, holocrystalline, medium coarse-grained

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rock composed of soda-lime feldspar, pyroxene, and olivine, some magnetite. Microscopic determination showed the minerals to be basic andesine, augite, olivine, magnetite, apophyllite, and brown biotite. The olivine is almost completely altered to serpentine and antigorite, with associated calcite and iron oxide. Kelyphitic structure is well developed about the olivine. Plagioclase, a pyroxene of small, variable axial angle, was noted in specimen 2V for the mineral in this specimen measured less than 15° .

The basalt is a black, hypocrySTALLINE, medium-grained porphyritic rock, with phenocrysts of labradorite, augite, and olivine in a groundmass of very small laths of feldspar, grains of augite, greenish to brownish glass, with such alternation producing chlorite, calcite, and iron oxide. The olivine is largely altered to serpentine.

Some of the basic rocks are intensely altered to a whitish yellowish white rock, with few partly preserved mineral parts. Under the microscope this rock is seen to consist of serpentine, calcite, quartz, amorphous silica, probably some kaolin, a few magnetite grains, and an occasional partly altered feldspar. Apparently the major portion of the ferrous minerals has been altered, the heavier constituents removed. Phases of more extreme alteration appear to contain chiefly amorphous silica, serpentine, and calcite in a form soft, friable, and of low specific gravity. This can be traced through gradations into the relatively fresh, unaltered basalt.

POST-ANDESITE RHYOLITE FLOWS AND TUFF

The post-andesite rocks consist chiefly of rhyolite flows and tuffs. Some of these were examined microscopically. A typical example of the flow rocks contained phenocrysts of acid plagioclase and orthoclase. Some quartz occurs in the devitrified groundmass. In some specimens examined microscopically, the mineralogic character of the rock was that of a trachyte rather than a rhyolite. It is sometimes impossible to determine whether one is dealing with post-andesite or pre-andesite flows. This can only be decided by detailed mapping of the formations and a graphic study of a number of specimens.

The tuffs vary notably in character. Some are white, differing little from the flows in general appearance, but showing small fragments of feldspar in a pasty matrix of minute magnetite and glass fragments. Devitrification of the glass is common. Another facies is composed of poorly consolidated, soft, v

ial with greenish spots. The distribution of this indicates that it is probably the latest facies of post-tion.

dal post-andesite rhyolite occurs on the Colorado claim on Queen Peak, and on the ridge south. Some amygdaloids, three-fourths to one inch in diameter, outh of Queen Peak.

face, the June Bell rhyolite is limited to a small area Bell claim; underground it is more extensive. It west wall of the Elko Prince vein on the 300 level and ootwall and hanging wall of the June Bell vein. This very hard, dense type, showing perfect flow struc-copic examination revealed phenocrysts of oligoclase, prisms and, rarely, minute prisms of zircon or tita-nated by occasional spherulites, in a dense, devitrified, micro-crystalline groundmass. The quartz occurs trographic intergrowth with feldspar, and as small, ches that are apparently secondary silica.

structure in the June Bell rhyolite has a consistent steep dip. On the surface it is in distinct discordance o Prince flows. The data obtainable on the contact wo formations were insufficient to determine whether rhyolite was intrusive into the Elko Prince rhyolite, Prince flows were resting on an erosion surface. l, there was not an opportunity to observe this body other than fault contact to other formations. From ilable this rhyolite cannot be designated as either intrusive. If extrusive, it is a uniform series of flows een either intensely folded, or steeply tilted by fault-der than the Elko Prince rhyolite, separated from it ral and erosional break. If intrusive, it is younger o Prince rhyolite and probably associated with the rhyolite flows in post-andesite time.

DIKES

and basic dikes occur in the district. They are more an is shown on the map. The dike rocks studied lly proved to be either rhyolitic or andesitic.

to the Missing Link vein is a dike which differs in om those generally observed in the area. This dike e a typical lamprophyre. It is black in color, very a general altered and softened. The dike is younger

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than the vein, which may be found on either side of it, cutting or splitting it to form a sheeted zone within it. The dike ran in width from one to three feet.

STRUCTURE

The Elko Prince rhyolite is the only formation in the district known to be definitely pre-andesite in age. Exposures of the contact between the two formations in the underground workings show the andesite lying conformably upon a series of flows of Elko Prince rhyolite. Following the andesite, rhyolite flows and tuffs were poured forth. The earlier flows of this period lie conformably upon the andesite, and are separated from a later one by an unconformity, marked by both erosional and structural features. The earlier lavas consist of rhyolite flows and well-consolidated tuffs; the later ones are poorly consolidated tuffs.

During the period of suspended volcanic activity, marked by an unconformity, erosion continued, accompanied by pronounced faulting.

The fissures, sheeted zones, and shattered zones were formed at this time and later became the channels in which the mineralizing and metallizing solutions moved, depositing their load and hydrothermally altering the wall rock. Some of these are zones of fracturing, suitable locations for solutions to circulate and deposit their contents; others are pronounced faults.

Following this period of disturbance, volcanic activity was renewed, and the country buried by the late post-andesite tuffs to a depth of several hundred feet. Erosion followed, carving out the present physiographic expression of the region. Neither veins nor other evidence of mineralization have been found associated with these tuffs, and the faulting and tilting affecting them is of minor importance.

The country is divided into fault blocks, and within the different blocks the attitudes of the formations vary from practically horizontal to nearly 60° dip. Faulting started in pre-mineral times, when it apparently reached its maximum intensity, and continued with less intensity during the period of mineralization, and there is some minor post-mineral faulting.

The major fault zones of the district, and the faulting which developed most of the vein openings, belong to two periods of pre-mineral faulting. Some of the fissures in which veins have formed were developed before the major faults, and have been offset by them prior to the mineralization. In these cases the

in both segments of the vein and along the section between the separated vein segments.

faulting has not been found to have produced few feet of displacement, and in general no evidence is found to indicate that great importance should be attached to post-mineral faults. In one case there is evidence of faulting of more than average intensity. This is at the east end of the Gold Crown vein where it is cut at a very acute angle. The character of the movement, and the direction of the displacement has not been determined. This is evident from the crushing and rounding of fragments of matter, which were found in the gouge along the fault, a few feet from the intersection.

The veins of the district strike $N 30^{\circ}$ to 60° W and dip 65° E to vertical dip. Some have steep west dips. There is no important mineralization strikes $N 10^{\circ}$ W to 80° west. The major pre-mineral fault zones have an east-west trend and steep southerly dip. More mapping may show other trends for major pre-mineral

ORE DEPOSITS

DISTRIBUTION AND CHARACTER

The ore deposits of the Gold Circle District lie in a highly altered zone where the rocks have been leached and bleached to a light gray color with occasional tints of brown and red iron stains. This leached and bleached area roughly coincides with the distribution of the veins. Near the mineralized channels alteration has been most intense, with devitrification of the groundmass and destruction of all ferromagnesian minerals, and almost total destruction of the feldspars.

The principal veins lie in a zone from one to one and one-half miles long, extending in a north-south direction and approximately three miles long, extending in a north-south direction. Northwest of this area there has been found which may extend the metallized zone. The zone varies from one-half to one mile in width and extends from the base of the mountain to Queen Peak on the south and mapped in detail. The formations, veins, and structures are shown on the map. From a rapid observation of outlying areas, it is evident that the characteristics of the ore deposits in this area are typical of the deposits throughout the district. In the southern part of the area the rhyolite flows were not differentiated as in the third (Plate I).

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The veins occur as shattered zones, and sheeted zones, as fissure fillings in rhyolite, and along the fractured contact between rhyolite and andesite. The vein material is principally silica and brecciated wall rock, generally rhyolite, with small amounts of calcite and adularia. Fracturing has occurred repeatedly along these zones, and the vein material, as well as the host rock, has repeatedly undergone shearing and brecciation, followed by cementation. In general throughout the district, fissure fillings and sheeted zones in rhyolite form the smaller veins, a few inches to three or four feet in width. On the other hand, the shattered zones in rhyolite, and especially those along andesite-rhyolite contacts, form the larger veins, often ten to fifteen feet in width. Similar zones twenty and twenty-five feet wide have been reported. The tenor of the ore is generally higher in the sheeted zones and fissure fillings, but their small size, commonly only twelve to fifteen inches wide, makes them difficult to mine. The shattered zones contain the larger ore deposits of mill grade. A number of veins have been traced along their strike for distances ranging from 1,500 to 3,500 feet.

VEINS AND ORE SHOOTS

The veins were formed along open fissures or zones of brecciation which existed during the period of mineralization. The fault controlled the distribution of the veins, their physical character, their length, width, and trend. Within such veins there are ore shoots. Any factor that may have acted physically or chemically to localize or aid in the formation of the ore shoots will be considered a "control."

The major ore shoot on the Grant-Jackson vein, which occurs

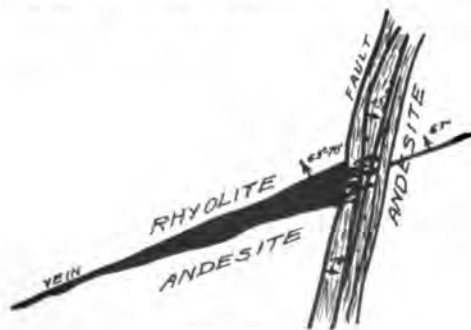


FIGURE 2

Plan of Major Ore Shoot in Grant-Jackson Vein at Intersection with Preminereral Fault.

in the southern portion of the Jackson claim and the north portion of the Grant-Jackson claim, is an example of an ore shoot formed at the intersection of a vein with a fault (Fig. 2). The Grant-Jackson vein intersects a strong pre-mineral fault about ninety feet inside the north end line of the Grant-Jackson claim, and here the major ore shoot occurs. This ore shoot starts at the fault and is inclined upward at a flat angle

levels the stope length 200 feet, respectively. been carried over 500 feet on the 165 level, and no side the zone of influ-

fault contact between the zone of finely brecciated material recemented by sugary material was apparently the contact with the andesite footwall. The zone is 100 feet thick. North of the zone is the zone of brecciated material.

One of this ore shoot: between the surface opening partly filled with material that occurred (Fig. 3).



FIGURE 3
Section Through Major Ore Shoot in Grant-Jackson Vein with the Mechanics, Which Aided in Its Formation, Illustrated.

than the fault and was fault zone and to the ion movements on the

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fault, centering near the footwall, helped keep a channel of mineralizing solutions to enter the vein and cement the fragments together; for later solutions to replace earlier material, and finally for the metallizing solutions to deposit a load of gold and silver.

The Missing Link vein is a typical fissure filling along a single fissure, and again in a sheeted zone in rock, or in the lamprophyric dike which courses with for some distance. The ore shoots do not show any control as in the case of the Grant-Jackson ore shoot. The filling varies in character and in richness. General pay streaks contain both gold and silver, with the silver predominating, but pay shoots do occur in which either metal predominates separately, in ore shoots within a few feet of each other, indicating two stages of metallization with the possibility of overlap between them. As a whole the pay streaks are dependent on gold for their commercial value. This is true of the ore shoots throughout the district.

The Elko Prince vein is a fissure filling along a steeply dipping wall, with considerable displacement, with the June Bell rhyolite on the east wall and the Elko Prince rhyolite on the east wall of the 300 foot level. The vein will average about two feet in width commonly, in addition to the siliceous vein matter, and several inches to a foot or more of gouge developed on the walls. The walls are firm and well defined. On the 450 foot level, mining operations were extended over 1,500 feet along the vein. The 450 foot and 600 foot levels were examined, but these levels were only briefly examined. They were partly reopened. Some mining was done on the 750 foot level, and a winze from the 750 foot to the 900 foot level. The north end of the vein was sunk in ore average 150 feet. The main ore shoot was 630 feet long on the 450 foot level, averaged fifteen inches in width; on the 600 foot level it was 230 feet long, and by November, 1917, 230 feet long on the 750 foot level showing an average width of 15 inches.

The control is evident for the ore shoot in the vein varies as much as 5' either direct or indirect. There are slight variations in the strike, but they have no effect on the metallization.

Plan of
Vein at 1

shoot sta

W. H. "The Mines Handbook" Vol. XIII, 1918.

Bell vein is a fissure filling in rhyolite. The average vein matter is less than a foot. An ore shoot opened the 300 foot level appeared where small step faults in. The ore shoot continued for 120 feet south of faults, to a point where it was intersected by a fault the hanging wall, where it turned and followed the east. Along the fault the ore was in place, but was developed. A similar occurrence was noted on the 600 the south end of the Elko Prince vein, where the was encountered.

shattered mineralized rhyolite of milling grade along esite contacts and in rhyolite have been reported old Crown vein and the Rex lode. These zones are the fissure fillings and range from five to twenty-five

al movement along the Gold Crown vein has been Emmons. This was also noted by the author at the d of the vein, near its intersection with the Colorado , which cuts the vein at a very acute angle and appar- ates it. This fault also shows definite evidence of movement. Large, well-rounded boulders of high- ve been found in the soft gouge along the fault, near on with the Gold Crown vein. The ore is typical ein matter, recemented. It may have formed in the intersection with the vein, and been broken up and later movement on the fault; or it may have been he vein as "drag ore" when movement occurred along he size of the boulders, one of which weighed several indicate an original deposit of more than average

ore two to three inches wide, assaying several thou- per ton, occurs in the Gold Crown vein at its inter- the fault. Northwest of the fault, along the vein, thers out into fine seamlets within twenty-five or This ore is similar mineralogically and comparable in boulders found in the gouge along the fault adjacent of the intersection. Surface exposures are poor in d underground development is not sufficient to prove urther this is an ore shoot formed at the intersection with the fault, or that it represents a segment of a shoot. The information available favors the former Southeast of the fault the vein has not been rec-

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fault, centering near the footwall, helped keep a channel of mineralizing solutions to enter the vein and cement the rock fragments together; for later solutions to replace earlier deposited material, and finally for the metallizing solutions to deposit a load of gold and silver.

The Missing Link vein is a typical fissure filling at along a single fissure, and again in a sheeted zone in the rock, or in the lamprophyric dike which courses with the vein for some distance. The ore shoots do not show any pronounced control as in the case of the Grant-Jackson ore shoot. The fissure filling varies in character and in richness. General pay streaks contain both gold and silver, with the silver predominating, but pay shoots do occur in which either metal predominates in value. The occurrence of the two types of mineralization, separately, in ore shoots within a few feet of each other indicates two stages of metallization with the possibility of overlap between them. As a whole the pay streaks are dependent on gold for their commercial value. This is generally true of the ore shoots throughout the district.

The Elko Prince vein is a fissure filling along a steep fault with considerable displacement, with the June Bell rhyolite on the west wall and the Elko Prince rhyolite on the east wall of the vein at or 300 foot level. The vein will average about two feet in width and commonly, in addition to the siliceous vein matter, there are several inches to a foot or more of gouge developed on the west wall. The walls are firm and well defined. On the adit mining operations were extended over 1,500 feet along the length of the vein. The 450 foot and 600 foot levels were extensively worked, but these levels were only briefly examined in 1917 when they were partly reopened. Some mining was done on the 750 foot level, and a winze from the 750 foot to the 900 foot level near the north end of the vein was sunk in ore averaging 15¢ per ton. The main ore shoot was 630 feet long on the 300 foot level and averaged fifteen inches in width; on the 600 foot level it was 810 feet long, and by November, 1917, 230 feet had been opened on the 750 foot level showing an average width of 15 inches.¹

No definite control is evident for the ore shoot in the Elko Prince vein. The vein varies as much as 5° either direction from vertical and there are slight variations in the strike, but these have no apparent effect on the metallization.

¹Weed, W. H., "The Mines Handbook," Vol. XIII, 1918.

ell vein is a fissure filling in rhyolite. The average vein matter is less than a foot. An ore shoot opened the 300 foot level appeared where small step faults met. The ore shoot continued for 120 feet south of the fault, to a point where it was intersected by a fault hanging wall, where it turned and followed the fault east. Along the fault the ore was in place, but was developed. A similar occurrence was noted on the 600 foot level at the south end of the Elko Prince vein, where the same was encountered.

Mineralized rhyolite of milling grade along the vein contacts and in rhyolite have been reported on the Gold Crown vein and the Rex lode. These zones are the fissure fillings and range from five to twenty-five feet in thickness.

Normal movement along the Gold Crown vein has been noted by Emmons. This was also noted by the author at the intersection of the vein, near its intersection with the Colorado fault, which cuts the vein at a very acute angle and appropinquates it. This fault also shows definite evidence of recent movement. Large, well-rounded boulders of high-grade ore have been found in the soft gouge along the fault, near the intersection with the Gold Crown vein. The ore is typical of the vein matter, recemented. It may have formed in the gouge at the intersection with the vein, and been broken up and moved by later movement on the fault; or it may have been dragged into the vein as "drag ore" when movement occurred along the fault. The size of the boulders, one of which weighed several tons, indicate an original deposit of more than average grade.

Ore two to three inches wide, assaying several thousand pounds per ton, occurs in the Gold Crown vein at its intersection with the fault. Northwest of the fault, along the vein, the ore breaks out into fine seamlets within twenty-five or thirty feet. This ore is similar mineralogically and comparable in grade to the boulders found in the gouge along the fault adjacent to the intersection. Surface exposures are poor in this area. Underground development is not sufficient to prove whether this is an ore shoot formed at the intersection with the fault, or that it represents a segment of a larger shoot. The information available favors the former. Southeast of the fault the vein has not been rec-

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MEGASCOPIC CHARACTER OF THE ORE

The open fissure filling is best represented by the ores of Missing Link, Elko Prince, and June Bell veins, where simple banding is the prominent structure. Within the individual bands the structure may be highly complex with intricate bandings, vugs, and cavities (Plate II, A and B). These features are depositional rather than deformational, though prior deformation obviously controlled the surroundings during deposition of the



PLATE II(A)

Complex Banding Within Simple Band of Vein Filling. The metallic minerals occur chiefly within the dark areas. Elko Prince Vein.

cleavage planes and the remaining calcite being removed by solution before complete replacement occurred (Plate III).

Plate IV shows typical brecciated rhyolite vein filling, recemented, from the upper part of the Grant-Jackson vein. The high-grade boulders found in the Colorado Grande vein were chiefly brecciated quartz and chalcedonic material, and some crushed country rock cemented together by a later deposition of silica (Plate V).

Large cavities are common along the veins and in the vein matter. Generally these are a foot or less in length, but locally they are several feet long and one or two feet wide. Frequently these cavities are lined with chalcedonic material, drusy crystals

vein matter, and thus determine the structure in the bands. There is notable variation in metallic content from one band to another, and also in the ratio of gold to silver.

The Grant - Jackson vein zone consisting of brecciated rhyolite (finely crushed material) and blocks ranging up to one or two feet in diameter), some quartz, and cellular quartz seams. These cellular quartz seams are apparently the result of replacement of the calcite along



PLATE II(B)

Intricate Banding and Vugs Within an Individual Band of Vein Filling. Missing Link Vein.



PLATE III

Boxwork Formed by the Replacement of Calcite by Silica Along
Venes, Followed by Solution and Removal of the Remaining Cal-
cic Complete Replacement Could Occur. Grant-Jackson Vein.

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and occasional well-formed clear crystals of quartz, one-half to three-quarters of an inch in length.

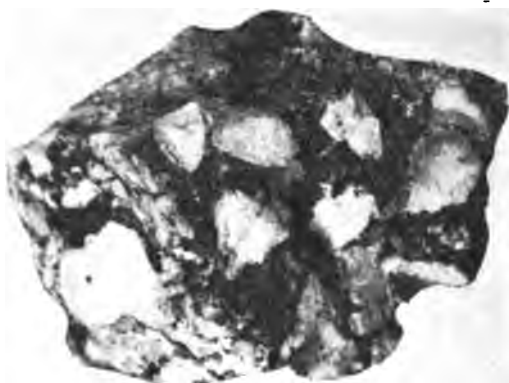


PLATE IV

Brecciated Rhyolite Vein-Filling Cemented by Finely Crushed Material and Silica. Grant-Jackson Vein.



PLATE V

Brecciated Quartz and Chalcedonic Material. Some Finely Crushed Fragments of Counters. Cemented Together by a Later Deposition of Silica. Colorado Grande Fault.

MICROSCOPIC CHARACTER OF THE ORE

Mineralogy—Neither the ore nor the gangue is complex mineralogically. Three metallic minerals, pyrite, stibnite, and native gold supply the bulk of the metallic content in the veins, with other metallic minerals appearing in small amounts. The gangue material consists of individual minerals and brecciated rhyolite. The principal mineral constituents are quartz, chalcedony, and calcite, with a small amount of actinolite.

f chlorite. The mineral species of the vein matter the following table in two groups, metallic minerals minerals, arranged in the order of their relative within their respective groups:

Minerals—

ite	FeS ₂	Abundant
stromeayerite	(Ag, Cu) ₂ S	Moderate
	Au	Sparse
chahedrite	Cu ₈ Sb ₂ S ₇	Trace to Rare
ustite	Ag ₃ AsS ₃	Rare
copyrite (?)	CuFeS ₂	Rare
alerite	ZnS	Rare

Minerals—

rtz	SiO ₂	Abundant
cedony	SiO ₂	Moderate to
		Abundant
ite	CaCO ₃	Sparse
alaria	KAlSi ₃ O ₈	Trace
orite	.....	Rare

almost always present in the ores of the district, but in the veins it is rare. It is usually the dominant metallic mineral, except in specimens of high-grade ore in which the minerals of the precious metals may dominate. Pyrite can be recognized by its high relief, hardness, creamy white color, the cubic form which is commonly developed, and its reaction in microchemical tests. It is fine grained.

Stromeayerite is the principal silver-bearing mineral. It can be found in all polished surfaces of the ores from the Elko, Elko Prince, and Colorado Grande fault, and Gold Circle. Stromeayerite closely resembles argentite (Ag₂S) in microchemical tests and appearance. The color of the mineral and the reaction with ferric chloride are more intense and more rapid in stromeayerite than on either argentite or jalpaite. The relief, and sectility of the mineral helps to identify stromeayerite. To further check its identity, light etching and polarized light are employed. Light etching slowly develops small, evenly spaced blebs on the exposed surface. This reaction distinguishes the mineral from argentite, which reacts intensely to light etching. The anisotropic character displayed under polarized light helps to differentiate it from jalpaite and argentite. Stromeayerite is considerably less abundant than the minerals already mentioned. It is identified by its color, relief, sectility, and its reaction with KCN on a polished surface.

Stromeayerite was recognized chiefly by its color, relief and reaction to all reagents used. This mineral was

observed in several specimens of ore but only as very small

Proustite, the silver sulph-arsenide commonly referred to as ruby silver, was not definitely recognized, but a mineral was observed as small bluish-white specks, almost blue in color against the gray and yellow background, in specimens from the Colorado Grande No. 1 claim and the Missing Link vein. The physical and microchemical properties observed in this mineral indicate that it is proustite. One assay for arsenic of mixtures from the district shows that proustite or some other arsenic-bearing mineral is more common in the ore than is indicated by a microscopic study. No evidence of other arsenic-bearing minerals was noted.

It is questionable whether chalcopyrite is present in the ore. On two or three surfaces a few small specks of a yellow mineral were observed, apparently having a higher relief and more brittle than the proustite were observed. Sphalerite was noted in a number of cases, occurring as very small grains often associated with stromeyerite.

Textural Character of the Ore—The gangue minerals are mainly chalcedony, quartz, calcite, adularia, and occasionally some chlorite. They will be discussed in relation to each other and to metallic constituents of the vein.

The veins were not completely developed at one time, nor were the minerals all deposited in them contemporaneously. This is clearly shown by the banding in the vein filling, the brecciation and cementation, and the replacement of one mineral by another.

In the sequence of the vein-forming processes the chalcocite material was deposited first along the fissures and zones of weakness. After the introduction and solidification of this material, movement occurred, shattering the earlier vein matter and sometimes the wall rock, producing new openings to be filled. Then solutions entered these openings and deposited crystals of quartz, cementing the fragments of chalcocitic material and country rock. It is probable that the adularia was formed during the deposition of the quartz veins at this stage, though in one or two cases it appears that some of the adularia belonged to vein matter older than the chalcocitic filling.

Following this stage, movement and shattering again occurred, followed by the introduction of fine-grained quartz. Thus three phases of silica deposition are seen. The specimens studied show the earliest to be chalcedonic silica; the next, medium to coarse crystalline quartz; the last, fine-grained quartz (Plate I and B). These phases of silica deposition may be assigned to a single period of vein formation, characterized by repeated opening of the veins, and recementation by deposition of

etc., from solutions of changing composition, and changing physical conditions.

the carbonate portion of the vein matter in the vein filling is more difficult. It appears that most

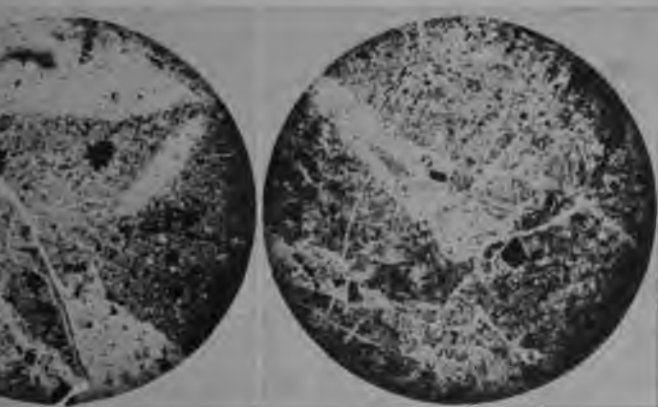


PLATE VI (A, B)
A **B**
 1. Chalcedonic silica
 2. Medium-grained crystalline quartz (light-colored area surrounding dark chalcedonic fragments).
 3. Seamlets of fine-grained quartz (light-colored) cutting both chalcedonic silica and the medium-grained quartz.
 Boulder of ore from fault gouge, Colorado Grande No. 1 claim.

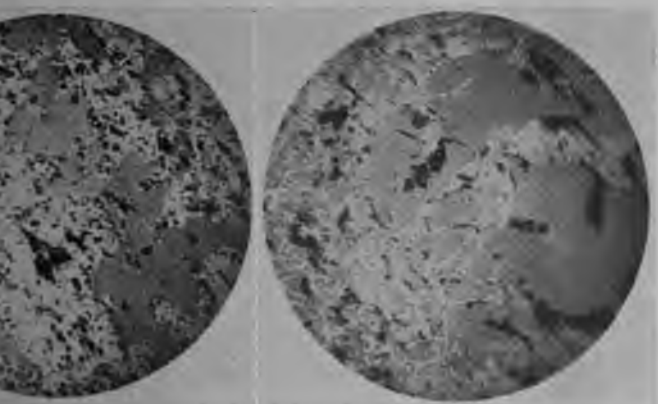


PLATE VII (A, B)
A **B**
 (Light-Colored Areas) Replacing Siliceous Vein Filling (Dark Areas).
 Link Vein.
 (Light-Colored Areas) Cementing Angular Fragments of Siliceous Filling (Dark Areas). In this surface there is not so strong a tendency toward replacement as in A. Missing Link Vein.

carbonate was introduced during the last phase of silica deposition immediately following it. Calcite of this period is particularly, replacing the earlier vein filling, and as a result, cementing the angular fragments. (Plate VII, A and B.) It is common to find calcite lining cavities in the ore.

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There is some evidence of an earlier period of calcite deposition prior to the silica. This was noted in one vein, the Jackson. In this instance the calcite was replaced by the silica which developed cellular siliceous boxwork along the cleavage planes in the calcite, and the remaining calcite was removed by solution before complete replacement occurred (Plate II). In some instances later siliceous solutions have coated the fracture areas with drusy crystals. Seams of this type are common between the boulders of rhyolite in the Grant-Jackson.

The metallic constituents taken as a group were introduced into the veins in the general order indicated graphically in Figure 4.

The metallic minerals were deposited later than the silica phase of silica deposition, though some pyrite occurs associated with silica of that period. The bulk of the pyrite and other metallic minerals are apparently associated with the

Pyrite
Gold
Stromeyerite
Tetrahedrite
Proustite
Chalcopyrite (?)
Sphalerite



FIGURE 4

Graphical Representation of the Order of Introduction of the Metallic Minerals in the Veins.

period of silica deposition. In every surface and section studied, metallic minerals were absent from the carbonate vein matter or were present only as inclusions associated with early silica filling. In one or two instances carbonate was observed as inclusions in pyrite; in others it surrounds pyrite and replaces it. The textural relation of the metallic and gangue minerals places the period of metallization as beginning with the second phase of silica deposition, and continuing possibly to the beginning of calcite deposition.

Pyrite is one of the most persistent minerals in the ore, being present in all the vein matter, and was present in the metallic solutions from the beginning almost to the close of the period of metallization. The earliest pyrite is found as isolated grains in the second silica phase. Later pyrite replaces earlier

ate VIII). In pyrite showing this relation, it is not
nd specks of gold scattered through it.

llizing solutions began depositing native gold with
after the close of the second period of silica depo-
gold also occurs in the gangue, filling seamlets and
S.

e cessation of gold deposition the solutions began
stromeyerite. The latter occurs with mutual boun-
ns to much of the gold.

ite and proustite probably accompanied the stromey-
copyrite and sphalerite seem to be contemporaneous
lk of the metallization.

ties still remaining in the ore are frequently lined with

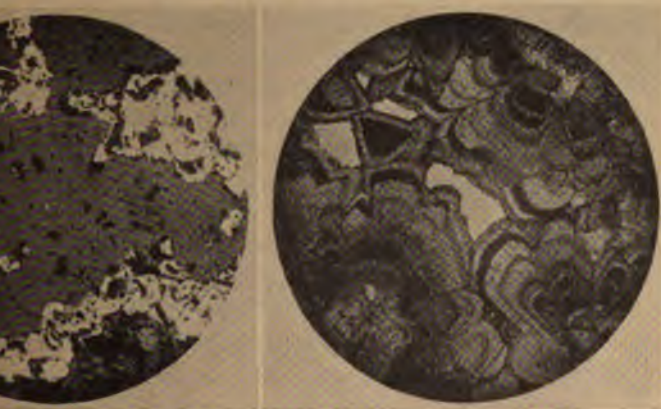


PLATE VIII

pyrite Replacing the Earlier Siliceous Gangue. This concentric
replacement of the gangue by pyrite is generally confined to
definite bands. Missing Link Vein.

PLATE IX

"Petal" Form Calcite Lining Cavity in Siliceous Gangue. Missing
Link Vein.

siliceous material. The calcite quite commonly develops
ns in cavity linings (Plate IX), and the silica is gen-
erally quartz.

GENESIS OF THE ORE

deposits of the Gold Circle district are found in a
volcanic formations of relatively recent age. These
y correlated with the formations developed by vol-
ty in the Great Basin region during Miocene time.
tion arises, at what depth below the then existent
re these veins formed? One means of answering

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this would be to determine the amount of erosion which has taken place since the deposition of the ore. From a study of the veins and the formations, it appears that the mineralization took place during the period of extensive erosion, following the first period of post-andesite folding and faulting, and prior to the extrusion of the late post-andesite tuffs. All the early formations were greatly tilted, and faulted prior to the mineralization. The ore was deposited along fissures and faults developed during this disturbance. With the present knowledge of the thickness of the formations, their positions and attitudes, it is difficult to make a reasonably accurate estimate of the thickness of the rock prism that was removed by erosion.

The greatest erosion appears in the vicinity of the Elko vein. Adjacent to the Grant-Jackson vein the formations are less disturbed, and it is possible to obtain a more definite estimate of the extent of erosion. The vein occurs along a normal fault between andesite and early post-andesite rhyolite. On the west wall side of the vein, along the ore shoot, the andesite is capped by fifty to one hundred feet of rhyolite. The amount of erosion is equal to the difference between the thickness of the remaining rhyolite and its original thickness. The thickness of this formation is approximately 400 feet. Though this may not represent the original thickness, it appears probable that it did not greatly exceed that which remains. These conditions therefore must have formed at relatively shallow depths below the surface.

The mineral associations, the structures in the vein, and the textural features of the vein filling all serve as indicators of the depth at which the deposits were formed. The typical minerals in these deposits are: Chalcedonic silica, adularia, grained pyrite, stromeyerite, and proustite. The typical structures are chambers, cavities, and open fissures along the vein. In the vein filling there are numerous cavities, banding, and cellular structure. The mineral assemblage and structures in the vein, and textural features of the vein filling are typical of hydrothermal mineralization at relatively shallow depths.

These features, taken with the evidence of depth indicators, serve to place the deposits in the category of the Comstock type, which is the type of deposit in the mines of Gold Circle, the Comstock, Tuscarora, Tonopah, and other important districts of Nevada.

SUMMARY AND CONCLUSIONS

Granite examined is one of extensive Tertiary volcanic includes flows of rhyolite and andesite, with which basalt flows and minor amounts of olivine diabase, and rhyolite breccia. Cutting these formations acid dikes are occasionally noted.

Volcanic series is divided into three major groups: the Elko Prince rhyolite, andesite, and post-andesite flows and tuff. The andesite overlies the Elko Prince with no apparent angular or erosional break. Conforming to these flows are the early post-andesite rhyolite and some interbedded tuff. Intense tilting and faulting mark a period of volcanic activity, ending in mineralization. After this period of disturbance and erosion, the andesite tuffs covered the region to a depth of several feet. This period was followed by some slight disturbance erosion cycle which developed the present topographic region.

June Bell rhyolite cannot be definitely designated as an intrusive or extrusive mass, it can be assigned to the pre-eruption only.

Ore deposits of the district occur as fissure fillings, veins, and shattered zones in rhyolite and along fault between andesite and rhyolite. The inclosing rocks show evidence of hydrothermal alteration.

Generally the ore shoots of the district do not show a trend. But in the case of the Grant-Jackson vein the ore shoot is controlled by slight flattening in the dip of the rock and by a strong premineral fault which intersects the zone of mineralization, movement occurred along this fault footwall, aiding in the opening of that portion of the footwall of the fault and keeping a channel open for circulating and metallizing solutions.

There were three phases of silica deposition and one of metal veins. The metallization is associated with the latter two, second, and all of the third phase of silica deposition. There is evidence of metallization associated with the calcite, and mineral introduced into the veins.

Evidence on the amount of erosion, the mineral assemblage, structural features of the veins, and the textural character of vein filling indicate that the formation of these veins took place at relatively shallow depths below the surface. These veins represent a typical epithermal type of deposit.

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Young, C. J., "Cooperation Among Small Mines," Engineering and Mining Journal, Vol. 106 (1918), 813.

¹"Mining Districts and Mineral Resources of Nevada," by Francis Lincoln.

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BULLETIN OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

Iron Deposits of Manganese Oxides Near Las Vegas, Nevada

By

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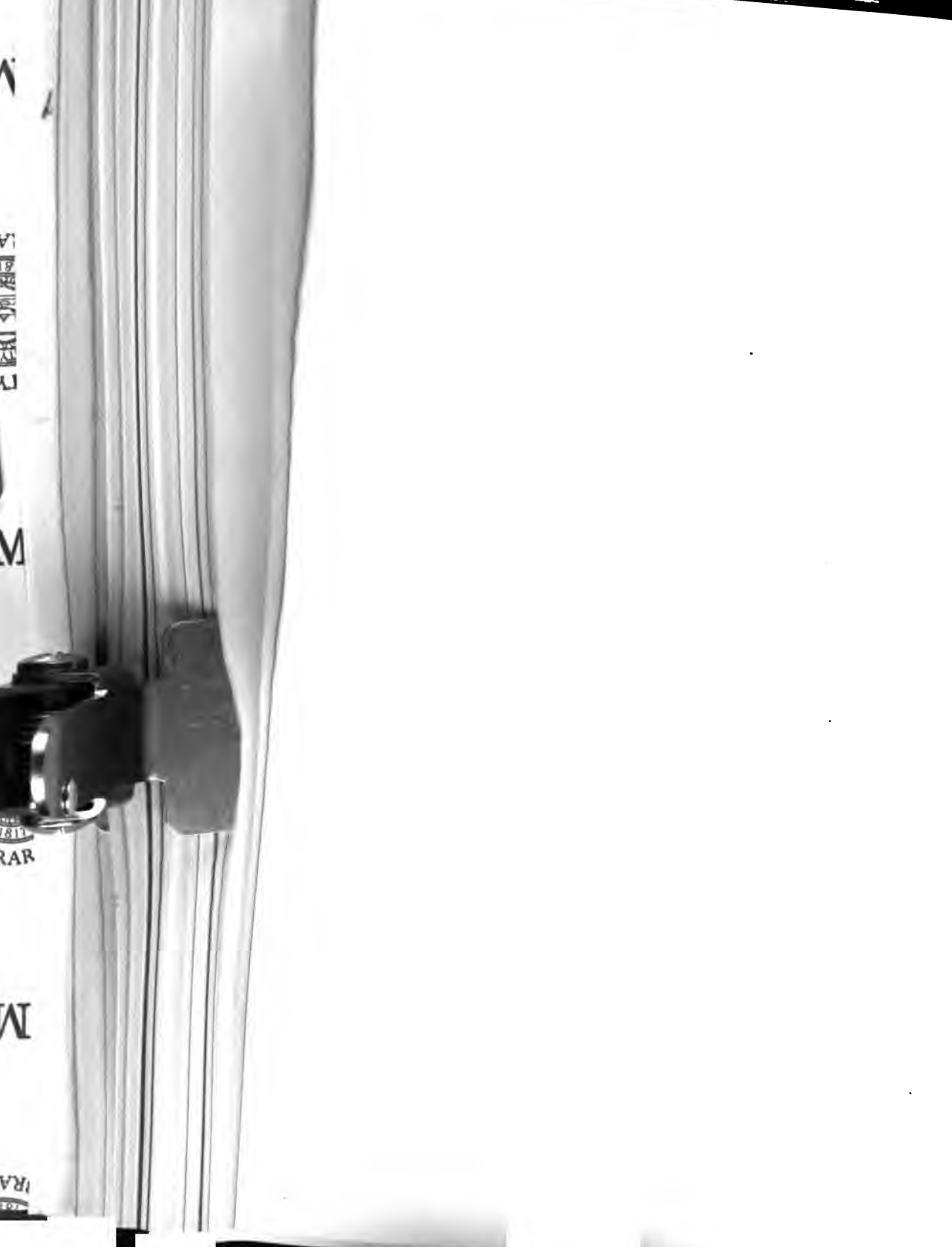
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DEPOSITS OF MANGANESE OXIDES NEAR LAS VEGAS, NEVADA

INTRODUCTION

The oxides of manganese are extremely common near the surface of the earth, without regard to the character of the underlying rocks, whether sedimentary, igneous, or metamorphic. In general, however, where they occur, or igneous, there are relatively few recorded instances of manganese oxides interlayered with stratified rocks as to offer convincing evidence that they are of sedimentary origin. In many places shallow exploration has revealed tabular deposits of oxides that lie roughly parallel to the local bedding of the rocks, but deeper exploration has indicated that they represent the weathered layers of carbonates, or silicates, concentrated or disseminated. Near Golconda, Nevada, tabular bodies of earthy manganese oxides that appear to be interbedded with calcareous tufa were interpreted by Penrose¹ and Harder² as manganese oxides, but later study by Pardee³ indicated that they are replaced layers of tufa.

The outstanding deposit of sedimentary manganese was first explored in the Tschiatouri field, on the south slope of the Caucasus Mountains in Russia.⁴ The age of these beds is referred either to the upper Eocene or Oligocene. Some beds of oxides occur in rocks of middle Oligocene in the Kirovsk district, Russia, and elsewhere in southeastern Russia. Except for some beds of oxides in unconsolidated Pleistocene age in the Bonneville Basin, Idaho,⁵ and in some deposits in several States, the writers know of no other deposits of manganese oxides in the United States that are interstratified with sediments except those here described and those near Topock and Artillery Peak, Arizona, which are the subject of a later report.

¹A. F., Jr., Manganese, its uses, ores, and deposits: Arkansas Geol. Rept. for 1890, vol. 1, p. 470, 1893.

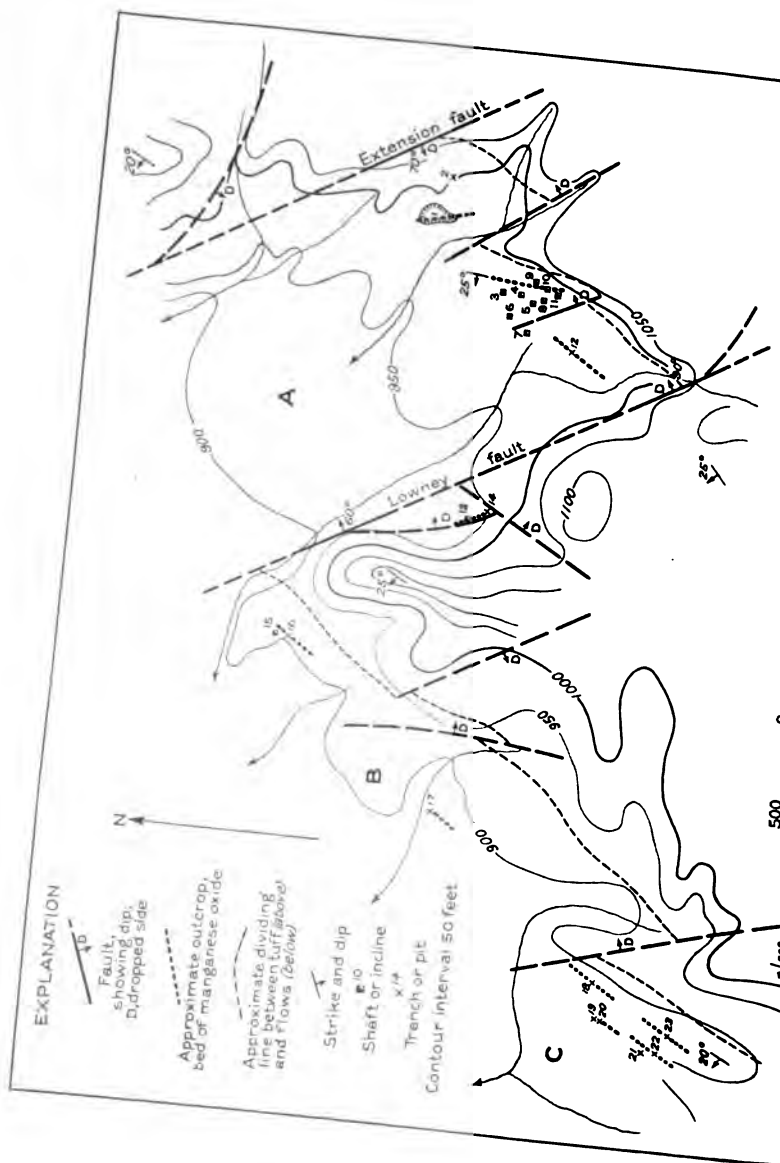
²Penrose, Manganese deposits of the United States: U. S. Geol. Survey Bull. 3-157, 1910.

³Pardee, Deposits of manganese ore in Nevada: U. S. Geol. Survey Bull. 6, 237, 1920.

⁴Considerable literature concerning these deposits. The most recent inquiry is that of W. de la Sauce, "Beitrage zur Kenntnis der Lagerstatte von Tschiatouri im Kaukasus" (Abh. prakt. Geologie und Bergbau, Band 8, 87 pp., 1926).

⁵Pardee, A manganese deposit of Pleistocene age in Bannock County, Idaho: U. S. Geol. Survey Bull. 795, pp. 211-221, 1928.

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mines in Oriente Province, Cuba, notably the Charco Sultana, manganese oxides are interbedded with sandstones of probable Eocene age.^{5a} Manganese deposits of both these localities have been known previously,⁶ but recent exploration has yielded information to clarify some debated questions concerning the deposits. In the following account emphasis is given to mineralogic features of the manganese-bearing beds, lithologic features of the associated beds, and the texture of the rocks.

GENERAL GEOLOGY

The area is concerned with an area about 3,000 by 4,000 ft. (fig. 1) that lies along the northwest slope of a group of hills south of Las Vegas Wash and west of the Colorado River, southeastern Nevada. The area is 16 miles south of Las Vegas and 3 miles south of Las Vegas Wash. The Boulder Dam is 10 miles southeast, but the distance would be nearly 20 miles.

The area consists of rugged hills, roughly 8 miles in diameter, is composed of numerous volcanic flows, flow breccias, breccias, and contains present diverse colors, light to dark reddish brown, yellow, and, although the area has not been examined, andesites seem to predominate in it. Few andesites seem to persist more than a mile, and those near the center dip outward from the center.

Along the northwest border of these hills the flows are overlain by relatively unconsolidated tuffs, which contain manganese oxides as well as numerous thin layers of gypsiferous material. At the base of these tuffs are thin lenses of coarse conglomerate composed of volcanic material from the underlying flows. In places these lenses are several feet in thickness. In this inquiry, attention has been given to the lower 200 feet of the unconsolidated beds which contain beds of manganese oxides and to the upper part of the flows and breccias, about 1,200 feet thick. The structures indicated on Figure 1 have been determined from a study of flows and overlying unconsolidated beds.

⁵ F. F. Manganese deposits in Cuba: Trans. Amer. Inst. Min. and Metall. Eng., 1920, pp. 87-89.

⁶ E. L. Jones, Jr., Manganese deposits of Clark County, Nevada: Eng. and Metall. Trans., 1918, pp. 775-777, 1918. Jones, E. L., Jr., Deposits of manganese in Nevada: U. S. Geol. Survey Bull. 710, pp. 222-232, 1920; Deposits of manganese in Arizona: Idem, pp. 143-153. Wilson, E. D., and Butler, G. M., Manganese deposits in Arizona: Arizona Univ. Bull. 127, pp. 71-76, 1930.

On the basis of the record of Longwell's work in the Muddy Mountains,⁷ as well as an intimate acquaintance with the area that lies southwest of these hills, the writers interpret the manganese-bearing sediments as approximately equivalent to the lower part of the Muddy Creek formation, of Pliocene age. The underlying flows, which resemble those found so far, and even more so, at sites considerably farther southwest, are tentatively referred to the Miocene(?).

THE VOLCANIC ROCKS

The upper 1,200 feet of the volcanic rocks that have been studied during this inquiry are separable into three groups as follows:

1. The lowermost flow is a reddish-brown latite about 1,000 feet thick. It forms the conspicuous hill 2,000 feet south of the Kids mine (Nos. 1 and 2, Fig. 1) and may be traced about 1 mile to the southwest, but is not conspicuous east and north of the mine. The rock shows rounded blades of feldspar and biotite in a matrix of reddish glass. In thin section the feldspar is determined to be sodic plagioclase, the biotite is large and stained to ferric oxide, and the glass matrix contains myriads of minute feldspar crystals 0.01 to 0.02 millimeter long. The rock contains about 10 per cent of corroded angular fragments of a still finer-grained rock.

2. Overlying the reddish latite flow is a group of light-colored latite breccias and flow breccias, andesitic breccias, and glassy flows. South of the Lowney fault pale yellowish and gray material predominates; north of it the andesitic material occurs sporadically. None of these rocks have been examined in thin section. The group ranges in thickness from 300 to 400 feet.

3. Of the three groups the uppermost flows exhibit uniform features throughout the area. They are entirely homogeneous in composition and range from vitreous to stony glass. They contain sparse feldspars to material that is finely crystalline. The feldspars are uniformly sodic plagioclase; a little fresh biotite is commonly present; hornblende and diopside are very uncommon. Quartz is present in one section; tridymite in another. Some varieties contain fantastically curved microlites; others contain myriads of feldspar crystals. Here, principally northeast of the Three Kids mine, the rock is partially altered to a greenish mineral, possibly celadonite. The alteration of the overlying reddish tuffs has occurred in small areas near faults and seems to have been caused by contact with the flows.

⁷Longwell, C. R., *Geology of the Muddy Mountains, Nevada*: Survey Bull. 798, pp. 90-103, 1928.

in the epoch of faulting. This group of flows is not thick.⁸

THE MANGANESE-BEARING SEDIMENTS

These are stratified materials that contain the beds of manganese oxides. The beds of manganese oxides are largely reddish-brown tuffs, with considerable volcanic material and gypsum beds. A single bed of gray pumice underlies the manganiferous zone in part of the area. Although an unconformity marks the contact of these beds with the underlying flows, it is not a sharp one. The dip is at right angles to the great divergence in strike or dip. The exposures do not permit the measurement of a comprehensive detailed section of the stratified materials. In a broad way, three parts may be distinguished—(1) the lowest, 100 to 150 feet thick, which is composed of coarse tuff; (2) the manganiferous zone, 60 feet thick, composed of very fine tuff with a little gypsum, fairly evenly bedded; (3) the upper, composed of fine tuff and gypsum beds, well stratified.

STRUCTURE

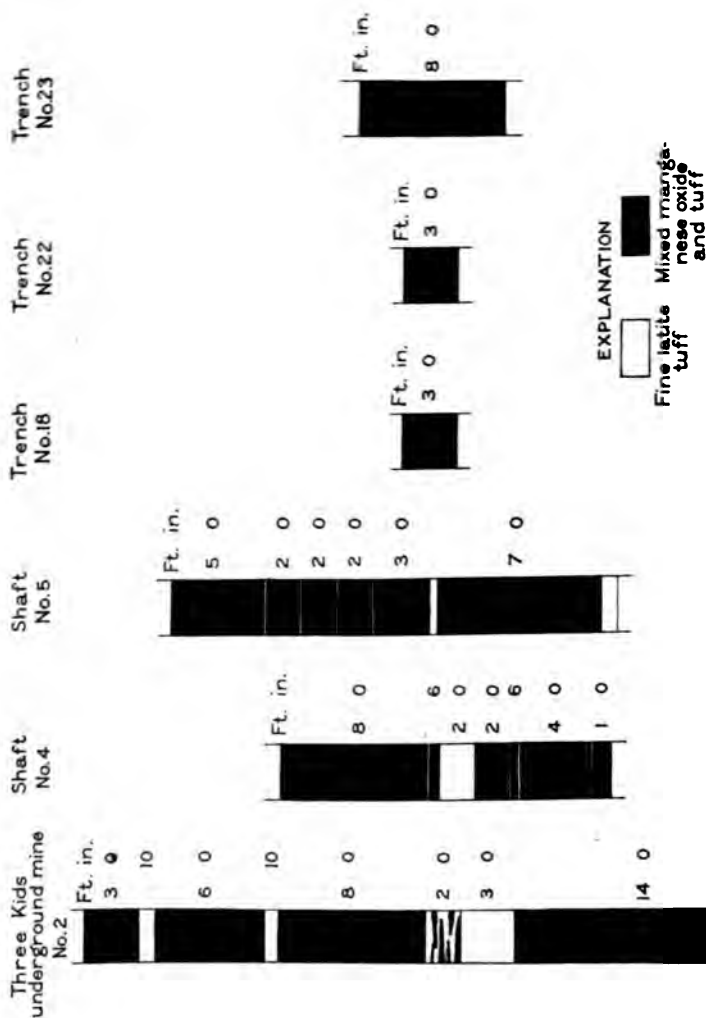
In the area shown in Figure 1 both the flows and the sediments trend northeast and dip northwest. The strike of the flows and sediments largely ranges from N. 10° E. to N. 30° E. and local variations seem to be related to the faulting. The dip of the flows is 20°–50° NW., but that of the sediments is generally far from 20°–25°.

The principal faults are shown on Figure 1; many faults are shown. The workings of the Three Kids mine are too small to show on this map. The principal effect of these faults is to divide the block of stratified tuffs between the Lowney and the Three Kids faults (Block A, Fig. 1) about 500 feet. The horizontal extent of the tuffs along the Lowney fault is about 1,750 feet. The fault is not only indicated by the offset of the tuffs but also by a prospect where it crosses the ravine south of the Three Kids mine. The Lowney mine shaft (No. 13, Fig. 1), which is deep but once deeper, explores a bed of manganese ore. It has been much sheared adjacent to a fault, probably the Lowney fault farther northwest.⁹ Both the Lowney fault, farther south, a sheared white clay-resembling sepiolite has been developed in the fault.

In the description of the district, E. L. Jones, Jr., described these rocks as quartz and tridymite are present in small quantity in only two of the rocks from this area examined by the writers, and as numerous and several analyses of similar rocks farther southwest show that it seems better to classify the flows of the Las Vegas area

Jr., interpreted this occurrence as a vein of manganese oxides rather than as a bed sheared near a fault.

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EXPLORATIONS

Following table summarizes the explorations that have been made in the area shown in Figure 1:

Principal Explorations on the Las Vegas Manganese Deposits

Three Kids mine, open cut; has yielded about 10,000 tons

Three Kids mine, underground mine, about 100 feet square; has yielded about 6,000 tons of ore.

Shaft 100 feet; struck manganese oxide bed.

Shaft 90 feet, along manganese oxide bed; dip 25°.

Shaft 50 feet, with drifts 50 feet north and south.

Shaft 40 feet; too shallow to strike manganese bed.

Shaft 35 feet; too shallow to strike manganese bed.

Shaft 35 feet; struck manganese oxide bed.

Shaft 15 feet; manganese bed not struck.

Shaft 15 feet; manganese bed not struck.

Shaft 15 feet; manganese bed not struck.

Shaft 15 feet; struck 3-foot bed of manganese oxide.

Shaft 15 feet; manganese bed sheared on fault.

Shaft 10 feet; on sheared manganese bed.

Shaft 24 feet; about 20 feet of low-grade manganese oxide.

Shaft 30 feet; 6-foot bed of low-grade manganese oxide.

Shaft 30 feet; streaks of manganese oxide in tuffs.

Shaft 30 feet; 3-foot bed of manganese oxide.

Shaft 15 feet; about 20 feet of low-grade manganese oxide. No fault.

Shaft 30 feet; about 20 feet of low-grade manganese oxide.

Shaft 1 foot of low-grade manganese oxide.

Shaft 3 feet of low-grade manganese oxide.

Shaft 8-foot bed of low-grade manganese oxide.

THE MANGANIFEROUS ZONE

Areas—Thus far, explorations have revealed beds of manganese oxide in three separate areas, and the sections of the manganiferous zone differ appreciably from place to place. The area (A, Fig. 1) is that included between the Lowney and Loney faults, in which lie the Three Kids and other mines. In these mines the bed of manganese oxide is divided by faults, but there is enough similarity in the sections to make satisfactory correlation. (See Fig. 2). As two distinct beds have not yet been proved in this part of the area, it is assumed that only one bed is present.

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In the second area (B, Fig. 1) a shaft is sunk 24 feet v in a bed of manganese oxide (No. 15), but does not pene base. About 30 feet southwest of the shaft a trench (reveals 6 feet of low-grade manganese oxide, but does not its limits.

In the third area (C, Fig. 1) at least two beds of ma oxide have been explored by trenches and tunnels. Th ness of the lower bed ranges from 1 to 3 feet, but several near by reveal a bed about 50 feet higher that seems t least 20 feet thick locally. About 300 feet to the southv higher zone contains a single bed 2 to 3 feet thick (No. 2

Explorations about 1,000 feet farther southwest, bey limits of Figure 1, show clearly that there are at least t of low-grade oxides less than 4 feet thick separated by 0 feet of tuffs.

Existing explorations are inadequate to present a d definite picture of the relations and extent of the beds of but they indicate several conclusions:

1. Although the zone of manganese oxide beds is pe at a fairly definite horizon, 50 to 75 feet thick, the separa are highly lenticular.

2. Each lens, pursued generally northwest from the greatest thickness and greatest purity, splits into several separated by layers of tuff.

The Manganese Oxide—The manganiferous material p rather uniform physical properties at most exposures. T is uniformly dull brownish black and the texture is ea finely granular. No coarse grains or nodules were ob The material is so highly porous and hydrous that a cu which weighed only 81 pounds when removed from th lost 8 pounds after exposure to the air for a few m Jones records the presence of "psilomelane and other ha manganese oxides" at one deposit, but psilomelane was not n the writers. Some of the material from the western o is hard and coherent, but thin sections show that this is the presence of opal and chalcedony in the pores.

In the same part of the area (B, Fig. 1), where the m ferous layers are thinnest, some layers show sporadic disc ous streaks of a hard lustrous black material that breaks conchoidal fracture. A thin section of this material show of silicate minerals (plagioclase, orthoclase, biotite, and d

¹⁰Jones, E. L., Jr., op. cit., p. 226.

of the tuffs in the black manganese oxides. The material is brown in thin section and closely resembles, a hydrous silicate of manganese, which in part replaces and in part has replaced the silicate minerals. The oxides of manganese have not replaced the silicates. The local relations indicate that the silicate minerals and these oxides were laid down as sediments, but that neobasalt and chalcedony were probably formed later by circulating waters.

From No. 4 shaft (Fig. 1) shows a few sparse crystals of (?) about 0.2 millimeter long, doubtless formed after the earthy manganese oxide.

Jones¹¹ records the following analysis of the material from the Three Kids mine, made by Smith, Emery and Angeles:

56.04	MgO	1.41
7.08	CuO	.49
1.68	ZnO	None
1.85	P ₂ O ₅	.07
13.73	SO ₃	.43
2.07	As ₂ O ₃	.06
.02	K ₂ O + Na ₂ O	3.82
Trace	H ₂ O by difference	11.25

The ingredients recorded in this analysis are common to psilomelane, but the percentages of lead and copper are only high for material having the indicated origin, those of barium and phosphoric anhydride are low. The remaining materials are probably ingredients of the ore portion. Although small percentages of lead are found from a few places, that given above is unusual and is part of the evidence of the uncommon origin of the ore.

—Special attention has been given to the mineralogy of the manganeseiferous material in the hope that the mineralogical data might serve as criteria in determining the bedded characteristic manganese oxides elsewhere. Analyses and solubility tests have been made to determine the state of oxidation of the ore and the residues left after dissolving the manganese ore have been examined carefully. The writers are indebted to J. G. Thompson and W. T. Schaller, of the United States Geological Survey, for the analytical and special mineralogical tests which

¹¹ Jones, Jr., op. cit., p. 226.

Analyses of Specimens of Manganese Oxides, Las Vegas District

[Analyst, J. G. Fairchild]

Source of specimen	Analysis				Equivalent oxides
	MnO ₂	MnO	Mn	PbO	MnO ₂
Principal bed, Three Kids Mine.....	44.26	3.87	30.97	*5.65	41.90
Shaft No. 4	42.95	6.01	31.79	.44	39.33
Shaft No. 5	46.31	1.27	30.25	1.31	45.60

*In addition to lead oxide, this specimen also contains 0.72 per cent cupric oxide.

The manganese in most of the bedded material is readily completely soluble in sulphurous acid, and the residual material shows some peculiar minerals. The most abundant grains are volcanic glass, plagioclase, quartz, and biotite that largely range from 0.2 to 0.5 millimeter in diameter, but there are also numerous perfect crystals of the zeolite phillipsite and the carbonate of lead, cerusite.

According to W. T. Schaller, "The abundant mineral in mineral prismatic crystals is phillipsite. These crystals, visible when the manganese oxide is removed with sulphurous acid or with ferric sulphate and sulphuric acid, occur single and in twinned groups. They have an average index of about 1.475, and are nearly isotropic on account of low birefringence. When the manganese oxide is dissolved in hydrochloric acid, that acid also decomposes the phillipsite, leaving a silica skeleton with a variable index of about 1.45. These phillipsite crystals are similar to those found on parts of the Pacific Ocean bottom which have been described and illustrated in the report of the *Challenger* expedition.¹² On page 10 of that report it is stated that 'the crystals are often obscured by particles of manganiferous clay, but when these are removed with hydrochloric acid the form of the crystal becomes more apparent since a siliceous skeleton remains.' Plate XXII, Figure 1, shows isolated crystals like those from Nevada, and Figure 4 shows groups of crystals as well as twins similar to those observed in the Nevada material.

"The *Challenger* material was also described by A. F. Renard, who states that the zeolite crystals (phillipsite) are generally simple and isolated, whereas others form aggregates and twinned. Spherulitic groups and globules were also noted. The isolated crystals, of simple crystal form, average about 0.025 millimeter long and 0.005 millimeter wide. The Nevada crystals resemble

¹²*Challenger* Rept., Narrative, vol. 1, pt. 2, 1885.¹³Notice sur les cristaux de phillipsite des sédiments du centre de l'océan Pacifique: Acad. Belgique Bull., vol. 19, pp. 88-100, 1890.

the simple form is identical with Figure 2 of Renard's

Nevada material the crystals of high index and low index are probably cerussite. After treating the material with dilute (1:10) nitric acid, the filtrate contained lead. (Lead is soluble by this treatment.) When the residue from the first treatment is treated with ammonium citrate on the steam bath, the presence of lead in the solution indicates the existence of cerussite in the residue. When the residue from the second treatment is treated with hot hydrochloric acid, more lead is dissolved in solution and suggests the presence of a lead mineral other than cerussite and anglesite."

Concerning the origin of the deposits, Hale¹⁴ wrote "It seems beyond question that the manganese oxide is of sedimentary origin, having been laid down prior to the deposition of the Tertiary strata overlying the beds." Later Jones¹⁵ wrote: "The manganese deposits of the Las Vegas district have been formed by the replacement of tuffs and of sand and clay beds by the disintegration of volcanic rocks. Most of the deposits are clearly associated with faults and fissures, but a few are grade deposits in the bedding planes of sand and clay without any apparent connection with faults."

In the opinion of the writers the following features of these deposits support the theory of sedimentary origin against that of replacement:

In their broader relations, tabular bodies of manganese oxide are found in a persistent zone about 100 feet above the base of the series of volcanic tuffs and gypsum beds. Thin partings of tuffaceous material between the layers of manganese oxide are known to persist at least 100 feet in thickness without great change in thickness, even though the contact of the oxide is not precisely sharp and definite. In their dimensions the layers of both oxides and partings are lens-shaped. These features are consistent with the idea that the manganese was precipitated in intermittent playas under arid conditions. The most abundant oxide of manganese is brown earthy hematite and has been noted widely in residual deposits as well as in the unconsolidated material of recent origin,¹⁶ but does not seem to be a product of hypogene replacement.

A. J. Jr., op. cit., p. 776.

L. J., Jr., op. cit., p. 225.

D. F., A manganese deposit of Pleistocene age in Bannock County, Idaho. Geol. Survey Bull. 795, pp. 215-217, 1928.

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BULLETIN OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

—
PRUCE MOUNTAIN DISTRICT
ELKO COUNTY

and

—
HARRY CREEK (Egan Canyon) DISTRICT
WHITE PINE COUNTY

—
By F. C. SCHRADER
Geologist, U. S. Geological Survey

—
PREPARED AND PUBLISHED BY THE NEVADA STATE BUREAU OF MINES
IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY



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SPRUCE MOUNTAIN DISTRICT*

By F. C. SCHRADER

INTRODUCTION

A visit was made to the Spruce Mountain District in 1900. At that time only a few of the mines were being worked, but the writer received much additional information from the local companies and mining men.

LOCATION AND TOPOGRAPHY

The Spruce Mountain District covers an area about three miles long on Spruce Mountain, the southwestern peak of the Snake Range, in the southeast part of Elko County. It has been described in the report of the Fortieth Parallel Survey¹ and Lincoln.³ The principal supply points are the Southern Pacific Railroad, about 45 miles north, and the Nevada Northern Railway, 24 miles south. Freight is also hauled from and ore to Tobar siding, on the Southern Pacific Railroad, 25 miles north, and to and from Wells, 10 miles northeast.

Spruce Mountain is an isolated peak west of the axis of the Snake Range, with which it is connected by comparatively low ridges. It reaches an altitude of 10,400 feet, nearly 4,000 feet above the flat valleys that surround it on all but the east side. It has a rugged topography, particularly to the south and west. Silver Hill, one and a half miles to the north, has an altitude of about 8,900 feet and is separated from Spruce Mountain by the Silver Hill Pass.

The principal settlement, at Sprucemont, on the lower west slope of the mountain, at an altitude of about 6,940 feet, has a population of 100. It receives its mail and freight from Jasper.

GEOLOGY

SEDIMENTARY ROCKS

The sedimentary rocks of the district consist chiefly of dark-colored sandstone in beds from one to four feet thick, interbedded

*By permission of the Director, U. S. Geological Survey.

Expl. 40th Par. Rept., vol. 2, pp. 502-512, 1877.

Notes on Some Mining Districts in Eastern Nevada: U. S. Geol. Surv. Rept., vol. 48, pp. 67-76, 1916.

C., Mining Districts and Mineral Resources of Nevada, p. 55.

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with shale and quartzite. They are estimated to be about 20° SE. feet in total thickness. From fossil evidence they are related to the lower Carboniferous (Mississippian). Their structure is complicated by uptilting and faulting that accompanies the intrusion of the igneous rocks, but their prevailing dip is 20° SE.

IGNEOUS ROCKS

Igneous rocks are only sparingly present. They consist of granite porphyry, diorite porphyry, and lamprophyre that intrude into the sedimentary rocks. They are in general altered and are not well exposed.

A dike of granite porphyry 500 feet wide extends east across the mountain range (Figure 1). As seen in the Porphyry tunnel, opposite the Black Forest mine, this rock is a light-medium-grained rock with abundant phenocrysts of quartz and orthoclase as much as 0.2 inch in diameter in a fine-grained groundmass of the same minerals. A little biotite and hornblende and pyrite are also present. In places an increase in the amount of plagioclase marks a gradation toward monzonite porphyry. The rock in the tunnel has been thermally altered and is much weathered. The feldspar is kaolinized and the biotite changed to chlorite and iron ore. There are bands of fine-grained siliceous limonite about an inch in thickness that dip about 30° SW. The rock between these bands is traversed by numerous parallel veinlets or seams of aphanitic greasy-lustered secondary quartz. These features denote that after having been closely sheeted under pressure the rock was later altered and had its fractures sealed by quartz. Near the face of the tunnel the limestone has been metamorphosed and mineralized for a distance of 30 feet from the face.

A thin section of the granite porphyry from the Standard mine, at Sprucemont, shows secondary veinlets composed of six or more depositional bands of quartz, sericite, and calcite, which in places cut through the quartz phenocrysts.

The diorite porphyry is a fine-grained dark brownish rock, which occurs as small irregular bodies and dikes. It is composed mainly of plagioclase and hornblende, both later altered to kaolin, sericite, chlorite, and epidote.

A lamprophyric dike was noted in the upper tunnel of the Black Forest mine. It is a dark greenish-gray speckled medium-grained to fine-grained porphyritic rock, characterized by small phenocrysts of biotite, hornblende, and olivine, of which the biotite is the most abundant.

ndant. Considerable orthoclase and plagioclase are . Much of the biotite is altered to greenish chlorite, nde to actinolite and other products, and the feld-dote, sericite, and kaolin.

CONTACT METAMORPHISM

hyry dikes have in places metamorphosed the host ially the limestone, but usually for only a few feet contacts. The maximum extent noted, with one was 30 feet in the Porphyry tunnel of the Black ; but at the Spruce Standard mine metamorphism d 500 feet from any known intrusive rock.

of the Spruce Standard mine is a mass of rock greenstone that is about 500 feet wide and extends or more up the canyon along the Monarch road. This own as diabase, but microscopic study shows it to ilicate rock. It is dull or earthy to olive-green in ely crystalline, and homogeneous and contains dis-articles and veinlets or "seams" of galena. A light specimen of this rock obtained near the mine on the 2 claim is composed mostly of greenish garnet and h subordinate quantities of actinolite, diopside, and enes, and a darker olive-green specimen of the rock d of a mile farther east up the canyon on the Carrie is composed mainly of diopside and fluorite. The sm of this rock is believed to have been caused by sing along the granite porphyry dike on the south. uthern edge of the silicate rock zone, or between the f the zone and the granite porphyry dike, there are ent iron-stained knoblike bodies of quartz breccia, alled blowouts, the larger one about 500 feet in hich also seem to be genetically connected with the ohyry dike. After brecciation the quartz has been y silica and iron carbonate.

HISTORY AND PRODUCTION

r ore was discovered at the Killie (Latham) mine in r early discoveries were the Juniper, Fourth of July, Forest. In 1872-1873 the Ingot Mining Co. built a r at Sprucemont to treat lead carbonate ores and time smelted 35 tons of ore daily, but the plant was s. Just before the panic of 1907 the camp enjoyed

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a brief revival of activity, and it is said that for several years prior to 1910 a considerable tonnage of ore from the Black Forest mine was smelted in the C. M. Spence 50-ton furnace in the valley northeast of Spruce Mountain.

In 1913 about 10 men were working in the district and a small shipment of ore was made from the Keystone mine.

The total production to the end of 1930 has been about \$1,731,000. No record of the production in early years is available, but the estimated early production from the leading mines is \$700,000, and since 1901, according to the available figures and probably authentic reports, the production has been about \$1,031,000. According to V. C. Heikes, in the *Resources of the United States*, the production from 1912 and 1916 to 1928 was as follows:

Period	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1902-1912.....	72.88	253,953	174,184	2,306,829	.....
1916-1928.....	103.87	352,321	148,347	7,771,622	40,197

The most productive years were 1926 and 1927, with output valued respectively at \$243,043 and \$116,190; that of 1928 was valued at \$113,738. The next best year was 1924, with an output worth \$113,738.

In 1929-1930 the production as given by the mining companies was about 3,200 tons of ore, of which two-thirds came from development work in the Killie mine. This figure does not include minor output made by lessees in the Bullshead and Parker mines.

The production by mines in 1918-1930 is about as follows:

Mine	Period
Monarch.....	1918-1928
Black Forest.....	1924-1929
Killie.....	1926-1930
Parker.....	1929-1930

The chief sources of power are Diesel engines using fuel oil of 27° or more Baumé. Until recently only timber was used in the mines, but now Oregon fir is imported. The average miner's wage is \$5.50 a day.

As present transportation costs on the ore amount to 50 per cent of its value, the district eagerly awaits the opening of the proposed branch railroad that will connect it with the Western Pacific at a point between Jasper and Tobat

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the proposed branch is near Sprucemont, at an about 7,250 feet.

ORE DEPOSITS

deposits carry chiefly lead, silver, and copper, but zinc also. They occur as replacement deposits in the granite, mainly as bedded deposits in or between certain strata, as in the Killie mine, and as fissure deposits. In the granite they also follow seams and irregular fractures. In the hydrothermal zone they occur on the contact between the granite and igneous rocks. The bedded deposits have been the most productive. The ores thus far mined have been lead, zinc, and silver, and consist chiefly of carbonates, of which the lead carbonates have been more profitable than those containing

silver ores contain abundant limonite, together with hematite, wulfenite, and residual cores and kernels of pyrite. The copper ores contain malachite, chrysocolla, and chalcocite. In subordinate quantities of bornite and chalcocite. In the lead ores both smithsonite and calamine are present. In the brownish lead-zinc ores, as in the Killie mine, the structure of the limestone is preserved by veinlets of white smithsonite. In some of the sandy carbonate ores the structure of the limestone is preserved in great detail by the replacement of the limestone by the carbonate.

The ore of commercial importance has yet been found only in the Spruce Mountain and Black Forest mines, and no zinc occurs in the Black Forest. In general there is a marked decrease in the zinc content of the ores with nearness to the granite porphyry, as in the case of the Killie mine.

MINES AND PROSPECTS

The principal property holders and operators in the Spruce Mountain District are the Missouri-Monarch Consolidated Mines and the Nevada Standard Mining Co., Nevada Lead & Zinc Mining Co., Missouri-Monarch Extension Mining Co., Eastern Nevada Mining Co., Bullshead Mining & Smelting Co., and Humboldt Mining Co. The position and extent of the different properties are shown in Figure 1.

MONARCH MINE

The Spruce Mountain and Black Forest mines have been owned since 1906 by the Missouri-Monarch Consolidated Mines Co. The

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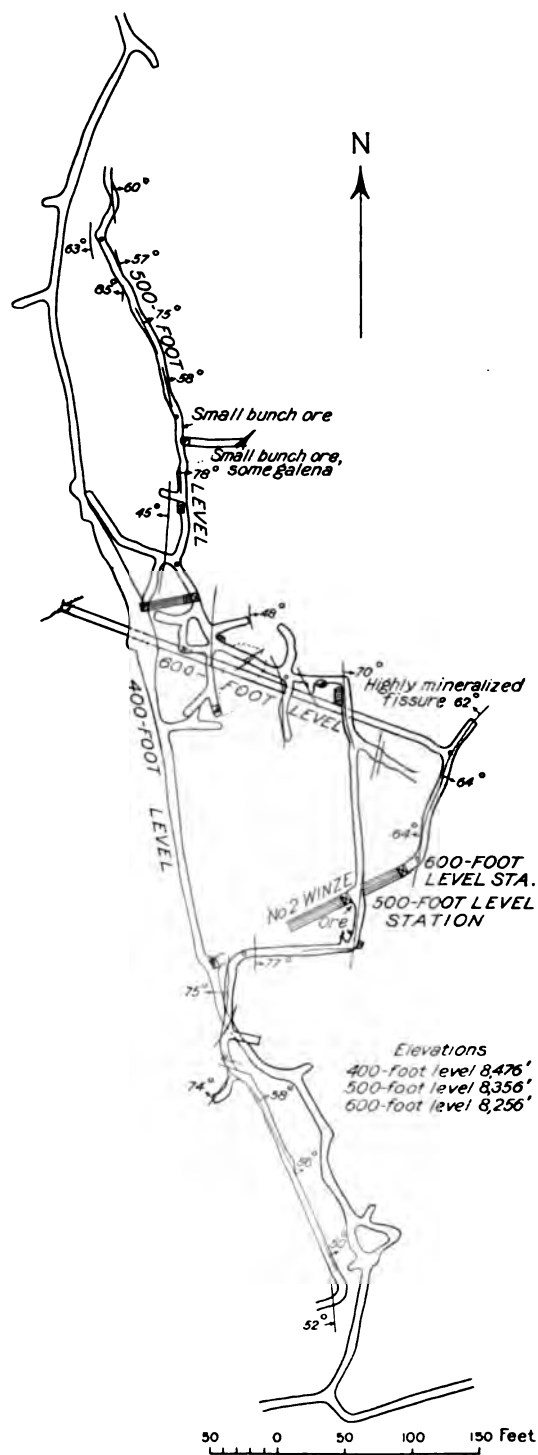


FIGURE 2—Plan of 400, 500 and 600 Levels in Monarch Mine

ne is about one and three-quarters miles east of on the middle of the steep western slope of Spruce with the main tunnel at an altitude of 8,455 feet. pest and one of the oldest mines in the district and re than 3,000 feet of work along three or more Figure 2.)

was worked in the early days of the district. In this mine had been idle since 1914, the Monarch Mining Co. began work. The Monarch tunnel was connect with the old workings, and shipments of ore 1919. Between 1919 and 1922 the production was 0 tons of ore that contained about 17 per cent of ounces of silver to the ton. The bulk of this pro- made in 1920. The ore was shipped to the Ameri- g & Refining Co., mostly by way of Tobar, but in was shipped also by way of Currie. The total value nents, on the basis of smelter returns, was about

ne Monarch Consolidated Mining Co. was succeeded arch Lead & Silver Co., and the mine was in that rgest producer in the district. Some of the ore ained as much as 22 per cent of lead and 24 ounces he ton. In 1926, 2,000 tons of lead-silver ore, chiefly s shipped. In 1928 the Monarch and Black Forest consolidated by the present company, which sunk e 600-foot level and did much development work. ntinued active until February, 1930, after which the el, 1,800 feet north of the Monarch tunnel and about her, was driven until operations practically ceased ving June. The company is now working seven men mines.

l the Monarch production came from the 300, 400, t levels. Extensive developments on the 600-foot ot thus far been encouraging. The work done -1928 followed the Fordna-Hardy ore shoot down foot level. This shoot raked to the southeast and foot level was 360 feet long. To the southeast of bodies were developed on the Monarch fissure, which N. 20° W. and dips 60° E.

he mine was said to have good reserves, and the n, though but little developed, was said to contain ore with a high content in silver and lead; but as

the cost of transportation has always been the great drawback. The company has postponed development in the hope that a railroad will soon be built into the district.

When operation is resumed it is expected to sink the shaft on the Monarch fissure from the 200-foot to the 400-foot level. The Bronco tunnel, now in 1,500 feet, will, when completed, reach a vertical depth of 500 feet, but indications along it so far have not been encouraging. The large dump at the Monarch contains 300 tons of low-grade brown oxidized ore said to contain 8 per cent of lead and 4 ounces of silver to the ton.

The chief veins are the Monarch, Thelma, and Big Fault veins. They strike nearly north and are about 800 feet apart. As the Monarch vein dips 65° E. and the Thelma 70° W., the two veins, as they continue their courses downward, should unite or intersect about 1,800 feet below the apex of the Monarch vein and about 1,000 feet below that of the Big Fault vein.

BLACK FOREST MINE

The Black Forest mine is on the steep northeast slope of Spruce Mountain at an altitude of about 8,500 feet (Figure 3).

After a period of operation by lessees, the Black Forest Mining & Smelting Co. began operating the mine on its own account in the spring of 1924 and made its first shipment in June of that year. During 1926, 3,000 tons of lead-silver ore, chiefly oxidized ore, was shipped for smelting and 1,000 tons of development work was done. By 1927 the company had produced and shipped 8,800 tons of ore that contained about 10 per cent of lead and 20 ounces of silver to the ton. Most of the oxidized ore came from a series of interlacing pipes or veins and chambers in the white limestone above the 1,000-foot level. The ore was shipped by way of Jasper to the American Smelting & Refining Co. at Murray, Utah. Transportation amounted to 50 per cent of the value of the ore. The production included 770 tons of ore that ran 20 per cent of lead, 18 per cent of iron, and 22 ounces of silver to the ton. This ore came from level A on No. 11 fissure.

The mine is opened by four tunnels, the chief of which are the upper and lower tunnels, spaced about 70 feet apart vertically. (See Figure 3.) It contains more than 7,000 feet of work. The lower tunnel trends S. 60° W. and has a length of about 1,500 feet. The most notable recent development work undertaken in the district is the driving of this tunnel and the Bronco tunnel to connect the Black Forest and Monarch mines through

the mountain at an altitude of about 8,500 feet. These tunnels, when completed, will have a combined length of 7,000 feet and a maximum depth of 800 feet. At the present time 2,300 feet of ground still remained to be crossed to make a connection. Much of the ground in the Bronco tunnel is soft, and wet and will require good timbering. The tunnels were designed primarily to facilitate shipment of ore from the mine on either side of the mountain and are expected to cross six or more fissures or mineral zones, in two of which tunnels have already been opened up on the Black Forest side. It will serve as a sheltered passageway between the two mines when the main roads over the pass are blocked by snow. The ore from the mine is conveyed about 2,900 feet and lowered about 1,000 feet by aerial tram to the loading station at the mouth of the tunnel.

The mine is near the eastern fault and, as shown in Figure 1, is divided except on the southeast side by the large dike of granite porphyry. Granite porphyry dikes also occur on the west side of the mine, and granite porphyry, diorite, and lamprophyres occur in the mine. A diorite dike cuts across the level about 600 feet from the portal. (See Figure 4, section.) There are also a number of cross faults, and the favorable places for ore are the junctions of the cross faults with the main fault.

Ore occurs chiefly along the northwest fault fissures, in large replacement ore bodies extending well out into the west. It also occurs as chimneys, pipes, and globular bodies of varying size, some more in diameter inclosed in crustified ferruginous shells from one to three inches thick. A tabular body of ore was being mined in the lower tunnel about 2,000 feet from the portal, averaged about two feet in thickness. The productive ore has been developed over a horizontal distance of about 1,800 feet through a vertical range of 400 feet (Figures 3 and 4) on levels spaced about 60 feet apart vertically. The mine has about 10,000 feet of underground work.

Prospecting has been done in the vicinity of the Dutch fissure, the Miller and Whim stopes, on the C level (Dutch level), and the Miller stope, on the A level.

The ore consists chiefly of a fine-grained mixture of carbonates of lead and copper containing about 20 per cent of silver, and 10 ounces of silver to the ton. In the deep part of the mine, however, the workings seem to be nearing the sulphide zone, from the sulphide ore found on the C level.

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KILLIE MINE

After being idle nine years the Killie (Latham) mine, in Killie Pass at an altitude of 8,900 feet (Figure 5) was reopened in 1926, and operated by the Spruce Consolidated Mines Co., which was succeeded at the end of the year by the Nevada Lead & Mining Co., the present owner.

During the last four years the mine has shipped about 100 tons of ore a month, or a total of 4,800 tons of \$15 ore that contains 22 per cent of lead, 13 per cent of zinc, 5 per cent of iron, 6 per cent of manganese, and 4 ounces of silver and 0.005 ounce of gold to the ton. The net profit was reported to have been \$100 a ton. No payment is made by the smelter for the zinc content, and a penalty is exacted if the zinc runs above 15 per cent.

**FIGURE 5**

Killie Mine in Killie Pass, Camp, and Banner Hill. Looking Northwest.

the time of visit a small force was employed in development work.

The mine is developed to a vertical depth of 250 feet, or 200 feet on the dip of the ore zone or lode, by several thousand feet of work, mostly on the 70, 85, 120, 160, 210, and 220-foot levels, of which the most extensive are the 70 and 160-foot levels. Killie shaft has a vertical depth of 220 feet. During the period of operation most of the mining was done between the surface and the 70-foot level, and most of the stopes in the mine are above the 120-foot level. Ore has recently been developed on and above the 120-foot level and on the 160-foot level. Jackson stope in 1930 had a very good showing of ore reported to contain 45 per cent of lead and 12 ounces of silver to the ton.

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er, 1930, the mine temporarily suspended operations, the depressed condition of the metal market. The camp buildings adequate to winter 20 men, the mine with a 25-horsepower gasoline hoist, and the company run by a 65-horsepower Premier oil-burning automobile. The ore is conveyed by aerial tram under Killie to the Killie mine 3,900 feet to the ore bin at the Black Forest tunnel, and thence under Black Forest power 2,900 feet to the truck-loading station. The tram handles 50 tons of ore each hour. The buckets hold 750 pounds each. The mine and camp pipe a rather scanty water supply through a spartan tunnel, in the porphyry dike on the adjoining side of the mountain.

The mine is chiefly in limestone about 800 feet north of the granite porphyry dike, and the ore bodies now being exposed extend from the glory hole northeastward down the dip for a known distance of 450 feet. The lode seems to be east of a north-south fault or zone of disturbance. Immediately on the west and northwest the rocks dip in the mine they have an average dip of about 40°. The section in part, so far as made out, is as follows, in order:

	Feet
limestone, ore-bearing.....	60
stone	50
silicified limestone.....	40

The lode or ore zone, beginning at the glory hole, has a extent of 450 feet down a 28° dip, a width of 100 feet on strike, and a thickness of 40 feet or more measured perpendicular to the dip. It is estimated to contain about 100,000 tons of mill-grade ore with a probable tenor of 10 per cent of gold, 10 per cent of zinc, 3 ounces of silver to the ton, and 1 ounce of gold.

The lode is in part localized by the intersections of the lode by fissures or slips, which strike and dip in various directions, some being curved in both strike and dip, so that it is difficult to follow any given ore body. The largest of these is the "big fissure," which strikes about N. 70° E., parallel to the dip of the lode, and dips steeply north northwest. The glory hole is about 80 feet east and west by 60 feet by 60 feet deep and has been worked underground to a depth of 80 feet, or 120 feet on the dip, below which the lode ceased. It has produced much good ore, some of

it very high in lead and zinc. The ore has replaced limestone and contains streaks of residual galena.

The Latham tunnel is on the 70-foot level and extends 100 feet east to the Killie shaft. The western part of the tunnel passes through the white barren limestone which, about 30 feet from the portal, is succeeded by the overlying blue limestone. Both formations dip very gently east. The rocks are clean and shattered. The white limestone is marmorized, and the blue limestone, which is in part ore bearing, is stained brown with lead and iron carbonates or oxides. Ore has been stored in places for a distance of 100 feet south from the tunnel.

Ore from part of the Jackson lode is roughly banded and consists mainly of brownish-gray cerussite and perhaps some oxidized lead minerals replacing limestone in part stained with malachite. Minute specks of dark copper oxide (melanconite) are also present. The silver seems to be associated with cerussite and other oxidized lead minerals.

Lead-silver sand-carbonate ore from the footwall side of the Killie lode consists of brownish-green fine-grained cerussite, closely banded and preserving in detail the structure of the limestone which it has replaced. This ore is friable and is said to contain about 40 per cent of lead and 20 ounces of silver per ton. The upper part of the ore body, which is commonly oxidized, is capped by half an inch or more of a yellowish-brown yellowish-green mineral, possibly lead oxychloride.

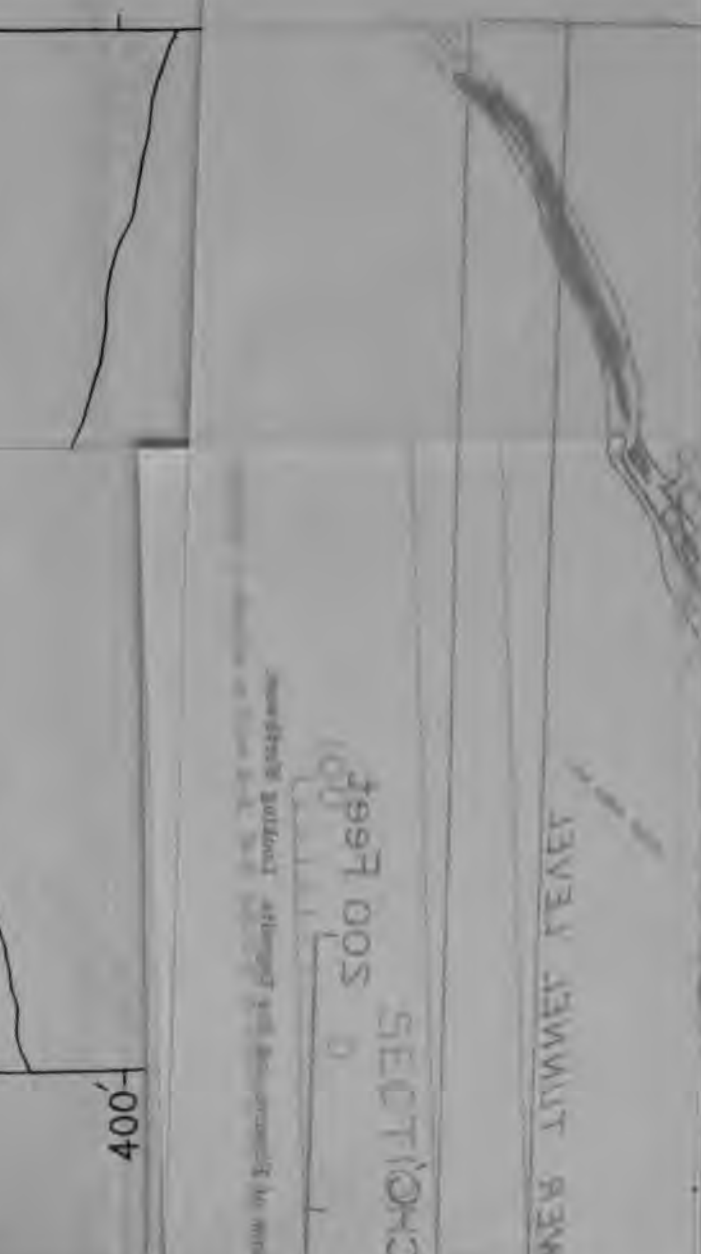
The brown ore that occurs generally throughout the mine is composed of a mixture of partly oxidized sphalerite and cerussite and traversed by seams and veinlets of smithsonite. It contains about 30 per cent of lead and an equal amount of zinc.

A lighter-brown and more compact variety of the ore, which is also general throughout the mine, contains considerable silver and is said to average 25 per cent of lead and 10 per cent of zinc.

In the oxidized ore are sporadic residual nodules of crystalline galena a few inches or less in diameter, said to contain about 65 per cent of lead and a little silver.

From the relatively small quantity of silver found in the sphalerite ore it is inferred that the silver in oxidized ore has been considerably concentrated by leaching.

Good indications of ore occur also in the vicinity of the mine in the low ridge extending from the glory hole northward. Here the limestone dips 30° W. Lessees mined five tons of



residual galena.
 n vein, which reaches four feet in width, strikes N. 30°

the winter of 1929-1930 from the adjoining Bingo

BULLSHEAD MINE

Bullshead mine of the Bullshead Mining & Smelting Co. on the northeast slope of Spruce Mountain about half a mile from Black Forest Canyon, at an altitude of about 7,900 feet. (See p. 6.) It has been a large producer and contains about 100,000 tons of underground work, mostly drifts, on both sides of

A smelter was built in 1917 and a trial run made with the Bullshead and Black Forest mines. The plant has since been abandoned. The Bullshead was one of the two principal pro-



FIGURE 6

Line in East Slope of Spruce Mountain, with Quartzite Reef in Mid-Ground and Top of Goshute Range in Background. Looking down the Canyon.

1918, when the total value of the district's output was \$100,000. It was also a large contributor to the district's output, producing \$53,428 in 1922, and was then said to have in reserve 100,000 tons of ore averaging 3 per cent of lead and 10 ounces of silver to the ton. In 1926, 150 tons of lead ore was shipped from the mine by lessees.

At the time of visit two small leasing parties were working in the upper tunnel about 800 feet from the portal and had found brown oxidized ore said to average 30 per cent of lead and 10 ounces of silver to the ton, some of it containing considerable residual galena.

A vein, which reaches four feet in width, strikes N. 30°

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E. and dips 30° ESE. in blue limestone. It seems to be faulted 15 to 20 feet on the west.

About 1,000 feet down the canyon east of the mine the rock, which is mostly bluish-gray limestone with a little slate, contains a bed of leaden to brownish-gray medium impervious quartzite about 100 feet thick. This bed dips 40° E. and seems to overlie the ore-bearing limestone and contains the Bullshead and other neighboring deposits. Its grains are subangular and corroded along the edges and in a slightly parallel arrangement which is evidently due to tectonic pressure. Considerable sericite has also been developed. The quartzite is in part heavily iron stained or mineralized. It contains a zone of mineralization along its base or footwall. This zone suggests that the quartzite in its former westward position was probably an important factor in ore deposition by acting as a barrier that checked or dammed back the ascending fluids that deposited the Bullshead and neighboring ores.

SPENCE MINE

In 1917-1918 sinking was done in the Spence copper mine which is said to have disclosed 15 feet of low-grade copper on the south contact of the granite porphyry dike and large and small stringers of good-grade ore in the dike, but the work was discontinued in the fall of 1918.

PARKER MINE

The Parker or Humbug mine, a new property owned by Mr. Parker and associates, is in the northeastern part of the district below the Spence mine, in a low flat-topped footwall at an altitude of about 6,950 feet. The claims are known as the Humbug group. In 1929 and 1930, 250 tons of ore with 22 per cent of lead and 9 ounces of silver to the ton were shipped.

The principal vein is in limestone. It is three feet wide, with vertical dip, and strikes N. 10° W. It has several branch veins.

The ore is mostly gray lead carbonate replacing altered limestone, much of which is stained reddish and yellowish with iron oxides, and in places contains disseminated coarse grains of pyrite. The ore occurs chiefly along the local replacement deposits in the limestone. Some ore is also found as replacement bodies in a fine-grained gray calcareous limestone that is locally called porphyry but is shown by micro-

be an impure lime silicate rock composed mainly of calcite with a little diopside and other silicates. It contains remains of crinoid stems, which are probably Mississippian age.

In the ore of the main lode it is reported that good ore is found in a fissure east of the main shaft.

The mine is opened by shafts to a depth of 80 feet. Owing to the steepness of the topography the mine can now be worked only by shafts, but it has been suggested that as other lodes are known to the east of this property it would probably pay to drive a 500-foot tunnel from the foot of the hill and thus gain considerable depth on the lodes.

BANNER HILL MINE

In 1925 the Banner Hill crosscut tunnel, driven on the Banner Hill group of claims, in the western part of Banner Hill, was advanced from about the 500-foot point to a total length of 1,000 feet, when work ceased after the death of the owners. The purpose of the tunnel was to prospect copper deposits.

SPRUCE STANDARD MINE

The Spruce Standard mine is at Sprucemont, in the lower west side of Spruce Mountain, at an altitude of about 7,000 feet, and is easily accessible. It was formerly a part of the Ada H. property. The mine is credited with an early-day production of more than 1,000,000 lb. in lead-silver-copper ore, in part very rich. It is reached by a shaft inclined at 65° (Figure 7), from which levels have been driven at depths of 165 and 265 feet. In 1926 several thousands of tons of oxidized lead ore containing silver was shipped by way of Tobar by the Paramount Consolidated Mining Company. In 1927, 100 tons of old slag from the Spruce Standard dump. In November, 1928, the mine was taken over by the Sprucemont Mining Co., of Elko, which has since reconditioned it by extending the shaft from the 165-foot to the 265-foot level, on which it has done extensive development work and mined a considerable amount of ore; but no shipment has yet been made. At the time of the last report six men were employed. The mine makes about 40,000 gal. of water a day. The surface equipment includes a Denver portable 220-horsepower compressor engine and a 10-horsepower Fairbanks-Morse sharpener and hoist.

The main lode strikes N. 35° E. and dips 60° SE. in limestone. It varies in thickness from a few feet to five or six feet in width. It is

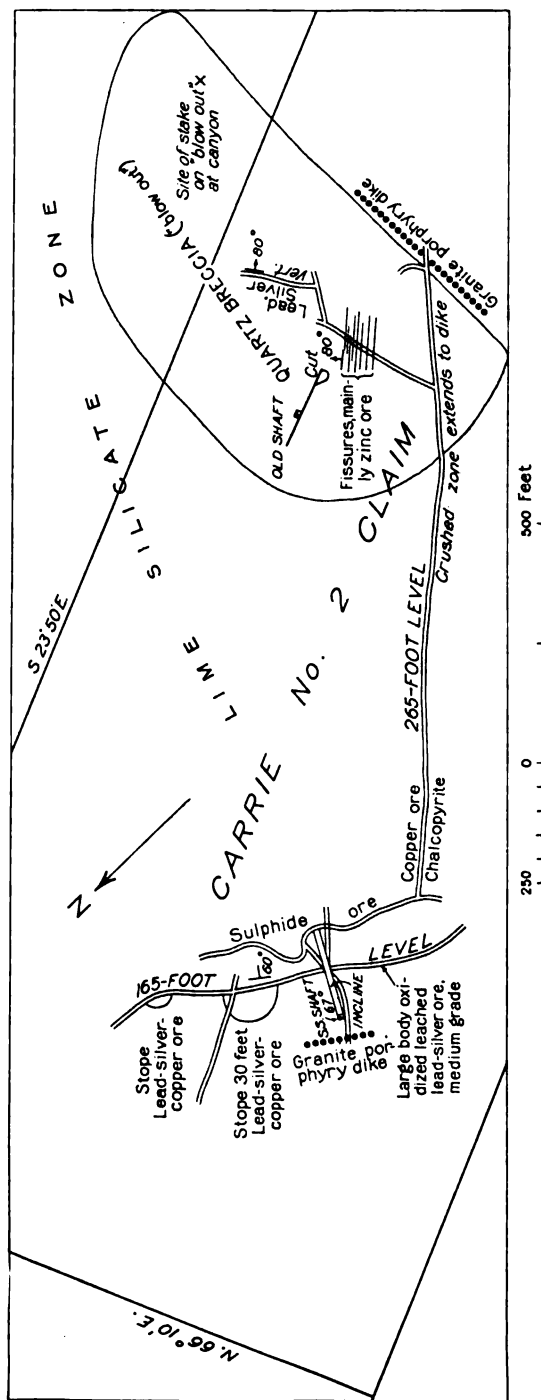


FIGURE 7
Plan of Workings in the Spruce Standard Mine.

or about 700 feet on the 165-foot level and 300 feet on foot level.

On the 165-foot level south of the shaft there is a large body of low-grade oxidized and leached lead-silver ore, and north of the shaft there are two good stopes of lead-silver-copper ore. The oxidized ore, much of which is friable, in general is stained brown or yellowish brown with iron oxides and is sparingly impregnated with copper carbonates, particularly malachite. The mineral content seems to be associated with the lead and copper

On the 265-foot level the ore is mainly sulphide ore containing lead, silver, and copper and may represent the top of the sulphide

The ore occurs chiefly as replacement deposits in the limestone and granite porphyry and along the contact of these two rocks. It contains quartz-pyrite gangue and is mostly crudely banded and

The ore minerals are chiefly galena, which is probably the most abundant, followed by chalcopyrite, pyrite, and a little arsenopyrite. The ore, however, is relatively pure fine-grained or medium-grained, and some is stained black with manganese. The lead-silver ore contains 12 per cent or more of lead and is high in iron. A polished section of the dark-purplish fine-grained chalcopyrite ore shows it to consist principally of chalcopyrite and pyrite, intimately mixed with a little quartz and carbonate gangue.

At a point near the south end of the drift on the 265-foot level a 400-foot crosscut has been driven southeastward to a granite porphyry dike. It is reported that geophysical prospecting has given favorable indications in this region. The rock in the crosscut is highly crushed and in part mineralized. In places there is copper ore, mostly chalcopyrite, has been found. The dike, which strikes easterly, is about 200 feet wide and seems to be a branch of the main dike, as shown in Figure 1. The dike is composed of the normal granite porphyry of the district and contains irregularly disseminated fine-grained pyrite, which also is associated with joint planes.

In the area there is a metamorphic zone 500 feet or more wide in which the limestone has been completely changed to a dark olive-green rock that has been locally called a diagenetic rock. Study of it in thin section, however, shows that it is composed chiefly of diopside, greenish garnet, and fluorite. The diagenetic rock may be accompanied by other pyroxenes and more commonly by tremolite and actinolite. In places the rock contains

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also a little secondary calcite and quartz. This meta- zone also contains, north of the spur dike, the larger of quartz blowouts mentioned on page 9, which likewise be genetically connected with the dike.

A dike of the granite porphyry occurs also at about 2 northwest of the Spruce Standard mine. It strikes N about parallel with the Spruce Standard vein, and is p connected with the ore deposits in that vicinity.

At 150 feet to the north of the dike a 250-foot branch off from the crosscut and runs east nearly parallel with t At about the 100-foot point it cuts a zone of closely parallel mineralized fissures 20 feet in width and dipp NE. Sphalerite is the principal ore mineral in this fissu After making a 70-foot offset to the southeast beyond sure zone the branch crosscut resumes its northeasterly for about 150 feet and follows a fissure of vertical t southerly dip that contains some lead and silver. The cut ends beneath the center of the big quartz breccia m "blowout."

The ore deposits in and near the Spruce Standard m believed to be genetically associated with the granite p dikes and to have been formed by thermal solutions tha lated soon after their intrusion.

The Ada H. mine, half a mile east of Sprucemont, h similarly prepared for active mining by the Sprucem Here two series of closely spaced mineralized fissures in ing northeast and northwest form a stockwork 1,800 more in extent.

OUTLYING ZONE

On the west the foothill belt of limestone for a dist eight miles north and two miles south of Sprucemont a width of one and a half miles contains many prospe outcrops of veins. Of this total width about 3,000 feet i heavily mineralized. Some of the properties in this zo example, the Chicago, Ohio, Paramount, and Cedar grou opened to depths of more than 100 feet. Some made sm puts in the early days of the district and seem to give of future production. The old Paramount shaft, on Par claim No. 7, about one mile northwest of Sprucemont, has of 200 feet and has produced considerable ore that is said run about 40 per cent of lead, 15 ounces of silver and \$5 to the ton, and a little copper. It is sunk at the interse two veins, one of which dips 60° N. and the other 80°

CHERRY CREEK (EGAN CANYON) DISTRICT*

By F. C. SCHRADER

INTRODUCTION

Present report is based mainly on a brief visit made to Cherry Creek District in August, 1930. The writer desires to acknowledge the aid and valuable information obtained from mining engineering reports, which were kindly furnished by men of the district, especially members of the New Standard Mining Co.

District has been described by Emmons,¹ Spurr,² Hill³ and Poln,⁴ on whose reports the present sketch down to the present is largely based.

LOCATION

Cherry Creek District is in the Egan Range, four miles west of the Northern Nevada Railroad, with which it has mail-stage stations. (See Figure 1.) It is 90 miles south of Cobre, on the Southern Pacific Railroad, 70 miles south of Shafter, on the Pacific Railroad, and 50 miles north of Ely, the seat of Esmeralda County. Cherry Creek, in the early days a populous town, has only about 40 inhabitants but is still the distributed to much of the surrounding mining country.

TOPOGRAPHY

Egan Range in the Cherry Creek District is a high, narrow ridge that separates Steptoe Valley on the east from Butte Valley to the west. The town of Cherry Creek is at an altitude of 5,000 feet. It is situated at the mouth of Cherry Canyon on the upper edge of a long, gentle slope that rises about 600 feet in the four miles west from the railroad station. North and south of the town the mountains rise by steep slopes and cliffs.

* Prepared by permission of the Director, U. S. Geological Survey.
¹ F. C. S. F., Egan Canyon District: U. S. Geol. Expl. 40th Par. Rept., pp. 45-49, 1870.
² J. E., Descriptive Geology of Nevada South of the Fortieth Parallel and Northern Portions of California: U. S. Geol. Survey Bull. 208, pp. 47-52, 1879.
³ M., Notes on Some Mining Districts in Eastern Nevada: U. S. Geol. Survey Bull. 648, pp. 161-172, 1916.
⁴ F. C., Mining Districts and Mineral Resources of Nevada, pp. 242-243, 1923. (Contains full bibliography.)

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and more basic where fresh, but in the mines it is highly altered, the feldspars being changed chiefly to chlorite and the biotite to chlorite and iron oxide. Gradations between the close relation of these different varieties are observed in thin sections studied under the microscope. Probably the ore deposits are genetically connected with the quartz monzonite, which is mapped by Hill as of probable Cretaceous early Tertiary age.

The dike associated with the Exchequer vein in the Imperial mine is a dull-gray fine-grained rather dense rock, which contains little or no visible quartz and corresponds closely to monzonite. In the neighboring Exchequer mine the dike along the same vein is a darker-gray medium-grained quartz monzonite porphyry with a microgranitic structure. It is distinctly siliceous and speckled with feldspar phenocrysts 0.2 inch or less in diameter. It contains more ferromagnesian minerals than the dike at the Imperial mine.

In the Walker drift of the Star mine the rock is greenish and appears to be intermediate between the two varieties described, but the microscope shows it to be an altered quartz monzonite porphyry. It contains finely disseminated pyrite and shows a parallel arrangement of the minerals that in places resembles flow structure. Much chlorite derived from biotite gives it the greenish tinge.

Diabase

The diabase is nearly black, with fine-grained ophitic or interlocking texture. It occurs as a dike on the tunnel level of the Star mine and probably also on the deeper levels, for fragments are found on the Star shaft dump. It is composed chiefly of basic minerals, plagioclase, augite and biotite. The rock on the Star dump has been hydrothermally altered. It is sparingly pyritic and contains much magnetite, much green hornblende, derived from biotite and chlorite and iron oxide derived from biotite. The diabase is believed not to be genetically connected with the ore deposits, although it seems to be older than the veins in the Star mine.

ORE DEPOSITS

HISTORY AND PRODUCTION

Ore was first discovered in the district in 1861 in Egan Canyon on the Gilligan vein, and, by 1866, \$60,000 worth of ore had been produced there. Estimates of production prior to 1902 range from \$6,000,000 to \$20,000,000.

The production for which figures are available, based

ts by V. C. Heikes in "Mineral Resources of the United is as follows:

	Ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Total value
1	.....	6,201.57	52.975	.....	.....	\$152,735
2	23,758	*\$246,154	334,720	96,053	645,788	566,670

*Value.

g in the district was most active from 1872 to 1883, and that period the population of Cherry Creek is said to reached 6,000. But decline followed, and production prac- eased in 1893, with the demonetization of silver. Later, the camp revived, and since 1895 work has been done al properties, notably the Star, Exchequer and Teacup which have been worked more or less steadily on a small wn to the present time.

5 to 1908 the Teacup mine was active and shipped ore. bout 1906 the Exchequer, which by some is credited early production of \$3,000,000, is known to have pro- 5,000,000 while it was worked by the Jones-Hand-Prior 1906 to 1910 the Star mine produced ore and later kept er pumped out until 1913, when it, together with the British, Chief of the Hills, and Mascot was acquired by ada Standard Co. From 1917 until the drop in silver the Mary Ann mine, a member of the Cherry Creek en being worked by the Cherry Creek Silver Dividend Co., produced \$35,000 worth of silver ore, which con- also about \$1 in gold to the ton. Prior to 1893 this reported to have produced \$65,000. The mine is opened y an upper and a lower tunnel, each 1,000 feet long. is and ore dip east in limestone and quartz monzonite. 0 to 1923 the Exchequer mine, reopened by the Silver Mining Co., of Pioche, produced 5,350 tons of silver ran \$16 to the ton, a total value of \$85,600. Since 1924, e Star mine was taken over by the Nevada Standard Co., it and the Exchequer have been worked on a mod- le and the Star has produced about \$27,000. The North a mine, in Egan Canyon, was worked in the fall of 1929 duced several hundred tons of ore.

TYPES OF DEPOSITS AS DESCRIBED BY HILL

e are two somewhat overlapping types of veins in the Creek (Egan Canyon) District. One type, represented by e West, Cocomongo, and possibly the McMurry prospect, principal value in gold carried in a white quartz gangue

that shows a minor amount of pyrite and less galena. The and by far the most important in the district is represented by the Exchequer, Star, Biscuit, Cherry Creek, and Gilligan which carry galena, sphalerite, pyrite, and rich secondary minerals. That there may be a transition between the two types is strongly suggested by the Exchequer New (Imperial) vein, in Exchequer Canyon, north of Cherry Creek. West of the canyon, on the Exchequer ground, the quartz carries the base-metal sulphides and contains more silver than the vein east of the canyon, on the New Century (Imperial) vein. What appears to be the same vein is not strongly mineralized but carries pyrite, gold, and silver. It may be that the pyrite and silver-bearing portions of the veins are those parts which have not been strongly mineralized and that the ore should all prove to be of the lead-zinc type, carrying more silver than gold. In both types the veins are strong in the quartz and tend to finger out where the fissure enters argillaceous country. This is particularly well shown on the Gilligan and Star veins.

"At the upper tunnel on the Cherry Creek Co.'s property the ore body is a mineralized quartz monzonite dike carrying pyrite, sphalerite, and pyrite. It is evident that the dike was mineralized after its consolidation, and it is believed that most of the veins of the district were formed shortly after the intrusion of the quartz monzonite.

"The lead-zinc veins have been crushed since the development of the original ores and have been enriched by descending waters which have deposited rich silver minerals such as argentite, proustite, and an antimonial silver-lead-copper mineral of uncertain composition. The enrichment of the Star vein, as indicated by the largest stopes, was greatest between the third and fourth levels but extended to a depth of 600 feet vertically in the croppings. At the Biscuit mine argentite and copper bonates are said to have been found to a depth of 1,100 feet on the dip of the vein."

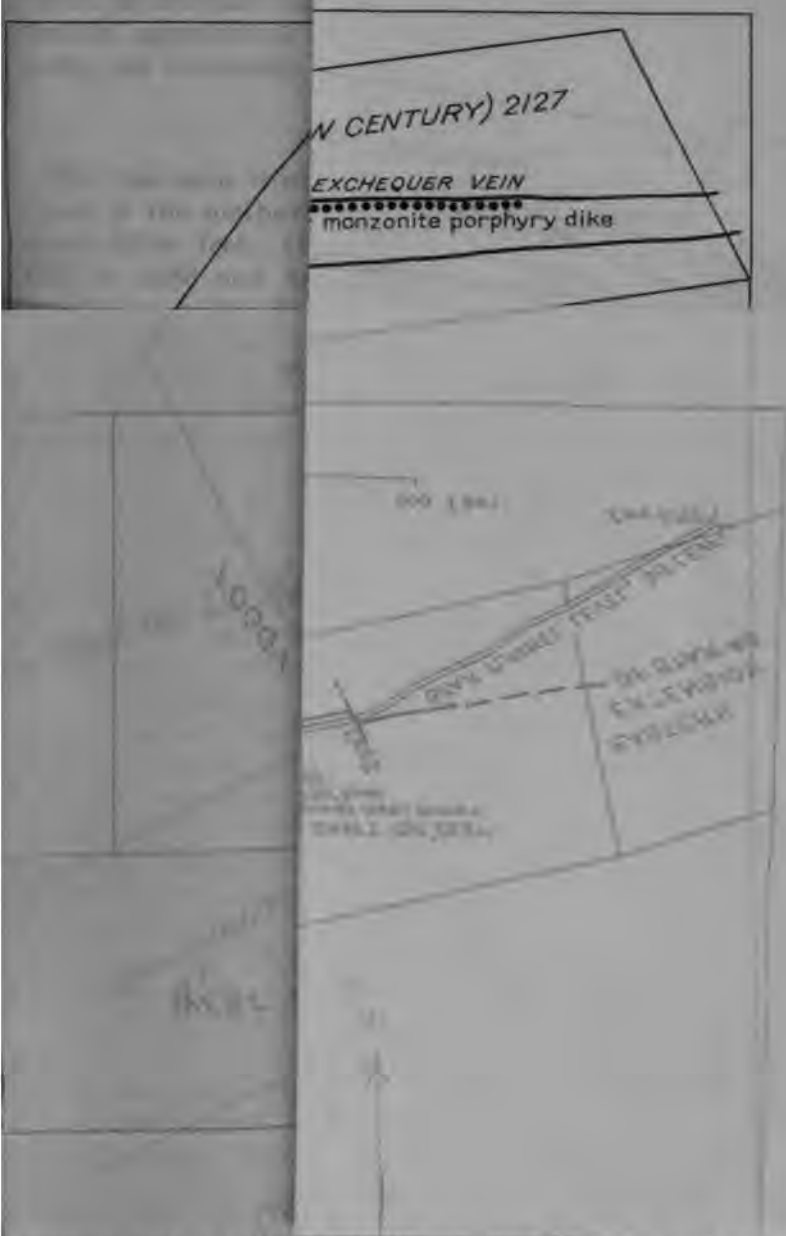
In nearly all the mines oxidation extends to depths of 300 feet.

MINES AND PROSPECTS

Only a few of the mines were accessible at the time of the survey. Their general distribution is shown in Figure 1.

STAR GROUP OF MINES

The Star group of mines is about two miles north of Cherry Creek, in the east slope of the range. (See Figures 1 and 2.)



worked with a force of 20 men under a cooperative leasing system that was said to be very successful and to yield about \$60 net a day. The company was also milling ore from the old Star

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STAR GROUP OF MINES

The Star group of mines is about two miles north of Cherru Creek, in the east slope of the range. (See Figures 1 and 2)

It comprises the mines or properties and claim groups formerly known as the Star, Gray Eagle, Exchequer, Imperial, and Nevada British, aggregating about 500 acres, which were consolidated under one ownership in 1929.

STAR MINE

History and Production

The Star mine is about one and one-half miles north of Cherry Creek in the southern part of the Star group at an altitude of about 6,700 feet. (See Figure 1.) It was worked chiefly in 1872 to 1883 and has produced more than \$6,000,000. After striking a heavy flow of water at the depth of 350 feet in 1880, the Star crosscut tunnel was started for drainage, and a little later mining was resumed and continued until the decline in the price of silver in 1893. Up to that time the mine had produced \$5,000,000 in gold-silver bullion, in which gold was the predominant metal by value.

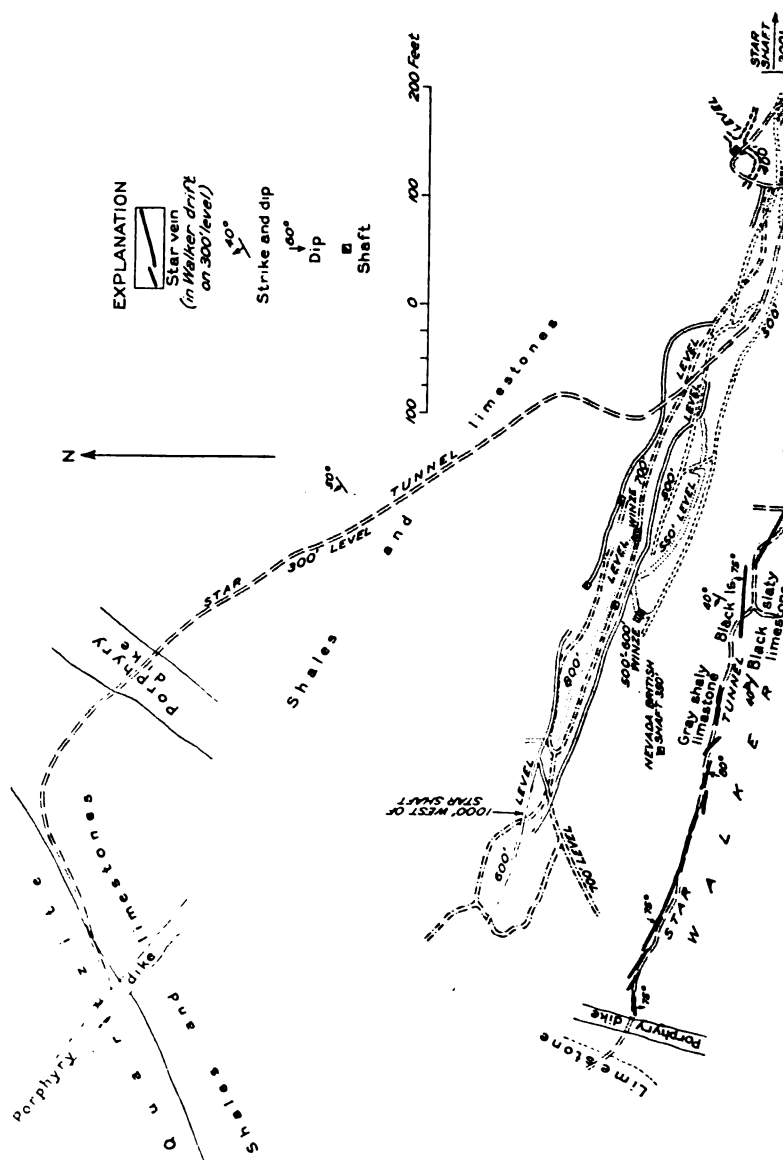
The Glasgow & Western Exploration Co. worked the mine between 1895 and 1910 and advanced the Star tunnel to a point 800 feet beyond the shaft, but the vein disappeared about 400 feet west of the shaft, and as crosscutting to the north failed to find it, it was supposed to have pinched out. An adequate water supply, however, was obtained from the tunnel, and before operations ceased in 1910 three unsuccessful attempts were made to mill the ore locally. The mine was kept pumped out, and in 1913 the Nevada Star Mining Co. began operations. As this company was operated with British capital, the outbreak of the World War forced a withdrawal of financial support, and the mine was again closed in 1914.

The mine was later worked by lessees until 1924, when it was taken over by the Nevada Standard Mining Corporation, under whose operation, directed by J. W. Walker, it has produced about \$27,000, more than half of which was in gold.

In 1927 Mr. Walker recovered the Star vein by crosscutting to the south on the tunnel level, and in 1927-1929 he drove the Walker drift 800 feet westward on the vein. During the fall of 1929, until the stock-market crash, the mine and mill employed more than 100 men, and 35 men were kept at work until the midsummer of 1930.

At the time of visit in August, 1930, the Star mine was being worked with a force of 20 men under a cooperative leasing system that was said to be very successful and to yield about \$60 net a day. The company was also milling ore from the old Star

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shaft dumps which were estimated to contain 10,000 tons, with a tenor of about \$6 to the ton in gold and silver, about equal in value, 7 per cent of lead, and 3 per cent of zinc. The concentrates produced contained 288 ounces of silver to the ton, considerable lead, and a small amount of gold, and were hauled by truck to one of the smelters near Salt Lake City. The extraction obtained in the mill was about 92 per cent. The company produced its own electric power and light. The miner's wage was about \$5.50 a day and that of the engineer \$6.

In March, 1931, the company was treating chiefly ore from these dumps in its flotation mill. The funds thus obtained were being used to drive the new Lower Star drainage tunnel, which was to have a total length of 2,000 feet and had then attained a length of 500 feet.⁸

Development and Equipment

The mine is developed by a three compartment vertical shaft 750 feet deep, with nine levels aggregating more than 15,000 feet of work. (See Figures 2 and 3.) Underground work is conducted through the Star tunnel, or third level, which drains the upper part of the mine. The tunnel, advanced from the 2,000-foot point since 1913, is now 4,200 feet long and intersects the shaft 1,400 feet from the portal at a depth of 340 feet. The lower levels (Figure 3) were under water at the time of the visit, and the old workings above the tunnel level were mostly caved and mined out.

A 20-stamp mill and cyanide plant has recently been remodeled to treat the ore by flotation, and the stamps have been replaced by a ball mill. The plant includes also a small ball mill, a tube mill, a 250-horsepower gasoline engine, an 8-horsepower Diesel engine burning 27° gravity oil, and an emergency Koler-Koler generator.

The Star tunnel discharges 15 cubic feet of potable water a minute, more than enough to supply the camp and a 100-ton mill, and this quantity will probably be considerably increased when the projected Star workings cut the water-bearing strata of the Exchequer mine. If much ore is found in depth in the Exchequer and Imperial mines below the Star tunnel level the company contemplates extending the lower tunnel, which will drain all the mines to a much lower level.

Deposits

The ore occurs in two nearly parallel quartz veins about 30 feet apart which cut across quartzite and shale. They are

⁸Nevada Min. Press, vol. 13, p. 1, 1931.

known as the Star or South vein and the North vein. The best developed in the quartzite and finger out and become barren in the shale. In a few places they are associated with the quartz monzonite. The Star vein ends at a quartz monzonite dike near the face of the Walker drift on the Star level, and both veins are said to cut the same dike near the ends of the sixth and seventh levels.

The veins have a known horizontal extent of about 2,200 feet and a vertical range of about 900 feet, with good indications of the deepest workings of continuing to greater depths. The Star vein extending from the seventh to the ninth level, the bottom of the mine, is said to be on the vein and mostly in good ore. This horizontal extent, however, the deposits include a zone extending 250 feet westward from a point a little west of the shaft. The Star or South vein strikes N. 72° W. and the North vein N. 78° W. Both dip steeply south for the greater part, but in places they stand vertical or dip steeply north. Their intersection on the sixth and seventh levels is about 200 feet west of the shaft. They have well-defined walls, but no gouge. The Star vein is the larger and more productive. It ranges from 1½ to 7 feet in thickness, with an average of 2 feet; one ore shoot mined had a maximum horizontal extent of 1,000 feet and ranged from 1 to 6 feet in thickness, average 2½ feet. The North vein, which is about 1 foot wide on average, has received comparatively little attention.

The veins in places are associated with quartz monzonite and are cut by small vertical normal faults that strike northeast, about parallel with the strike of the country. The part of the vein west of the fault is generally displaced to the south, as in the Star tunnel east of the shaft. (See Fig. 1.)

In the Walker drift the vein ranges from 1.2 to 3 feet in width and carries good ore through almost the entire thickness of the drift, near the end of which it ends against a quartz monzonite dike.

In the upper levels the ores are highly siliceous and oxidized but they become base in depth, where the ore minerals are mainly of galena, sphalerite, and pyrite in a roughly crystalline white quartz gangue. These sulphides, however, have been in part replaced by tetrahedrite, proustite, stephanite, pyrite, polybasite, argentite, and chalcopyrite, largely as pseudomorphs after the primary minerals, especially galena and sphalerite. These secondary minerals occur also as veinlets filling fractures in the vein and in the wall rock. Enrichment has extended

to the eighth and ninth levels, although here the ore is base, carrying about 8 per cent of lead and an equal amount of zinc.⁹ Ruby silver and tetrahedrite are present in the richest ore, and silver chloride and bromide were also noted in the oxidized ore.

The ore of the Star mine is said to average about a quarter of an ounce in gold and 20 ounces in silver to the ton, and about 8 per cent each in lead and zinc. It is not amenable to cyanidation. Some of the ore, however, is very rich in both gold and silver and is said to run as high as 800 ounces in silver to the ton. Yellowish-brown scheelite was noted in one specimen. A specimen of the rich gold-silver ore collected by the writer from the vein near the face of the Walker drift consists of vein quartz crudely banded with galena, sphalerite, pyrite, and ruby silver. The gold in the ore is mostly associated with the pyrite and sphalerite. Tetrahedrite, which is rich in silver, is also associated with the sphalerite.

A polished section of the rich ore from the Star tunnel level shows the metallic minerals in order of relative abundance to be pyrite, sphalerite, and galena. The sphalerite contains tiny elongated blebs of chalcopyrite showing a tendency toward parallel orientation. The rough sides of the specimen show wire silver, which has formed along minute seams in the quartz in sufficient quantity, it is believed, to account for most of the silver present. The wire silver is probably of hypogene origin.

A thin section of this ore shows a considerable quantity of a dark silver mineral which may be argentite and also contains small specks of what is probably gold associated with calcite.

According to Hall, who examined the mine in 1928, the reserves at that time amounted to 34,450 tons of ore but this figure did not include the ore in the vein above the Walker drift, which was a later discovery. As the vein carries ore throughout the length of the Walker drift, which is 800 feet long and 650 feet below the surface, it is regarded as containing a large volume of possible stoping ground between the drift and the surface.

Other engineers credit the Star mine with a proved reserve of 15,222 tons of ore containing about 30 ounces of silver to the ton and a possible additional reserve equivalent to 4,000,000 ounces of silver.

GRAY EAGLE VEIN

The Gray Eagle shaft lies about 900 feet northwest of the Star vertical shaft. It is 210 feet deep, and the collar is at

⁹Hall, Clarence, unpublished report on the properties of the Nevada Standard Mining Corporation, 1928.

an altitude of about 7,400 feet, or 650 feet above tunnel level, through which the vein will be worked. (Figure 2.) The vein strikes N. 60° E. and dips 45° NNW. It is composed of shale, limestone, and quartzite. It is about 3 feet thick and has a known length of about 1,600 feet. It crops out on the Gray Eagle and Chief of the Hills claims. On the latter it has been called the Mascot vein and is said to crop out at a height of 1,175 feet above the Star tunnel level. The vein is said to run about 0.3 ounces of gold and 8 ounces of silver to the ton.

EXCHEQUER AND IMPERIAL MINES

The Exchequer and Imperial (New Century) mines on the west and east side of Exchequer Canyon, constitute the northern part of the Star group (Figure 2) and are about 3 miles north-northwest of the Star mine, at an altitude of about 7,000 feet or 400 feet higher than the Star tunnel, by which they will eventually be drained. They were among the first mines worked in the district. They are on two approximately parallel veins, about 60 feet apart, the Exchequer or North vein and the Blue vein, which strike about N. 80° E., stand about 60 feet apart and have a length of about 3,000 feet on the property. The Blue vein is said to be known from outcrops to have a total extent of more than 4,000 feet.

The veins lie in the series of argillite, limestone, shale, and quartzite, which here has been much disturbed, and are associated with one or more dikes of the quartz monzonite porphyry. The ore is reported to run 22 ounces of silver and 0.05 ounce of gold to the ton, and much of the quartzite and quartz monzonite porphyry between the two veins is supposed to be sufficiently mineralized to form ore of milling grade.¹⁰

IMPERIAL MINE

The Imperial mine is opened by an adit 600 feet in length and a 320-foot shaft. The adit is driven westward on the Blue vein and intersects the shaft about 70 feet below the level of the Star tunnel. At the time of visit the shaft was accessible only to the level of the Star tunnel. The vein here consists mainly of a mineralized breccia in a fault zone about 11 feet wide and is associated with a fine-grained quartz monzonite dike which forms a considerable portion of its south wall and extends southward to the Star mine. The ore-bearing portion of the vein, however, is from 2 to 10 feet wide and averages about 4 feet.

¹⁰Hand, C. T., unpublished report on the Exchequer and Imperial mines, September 27, 1919.

There is said to be ore in the bottom of the shaft, but no large body of sulphide ore has been found. According to Prior,¹¹ the longest showing is on the 250-foot level, where the ore shoot for a length of 110 feet averages 6 feet in width.

The ore minerals are pyrite, galena, tetrahedrite(?), cerargyrite, stromeyerite, and argentite(?). A considerable portion of the ore is said to run about 30 ounces in silver and \$1 or more gold to the ton.

The ores are not as complex as those of the Star mine and can be cyanided. Cerargyrite, said to have been abundant in the surface ores first mined, was not seen in the present workings, although the ore now exposed is more or less oxidized.

The minerals are finely disseminated in the gangue and in part follow fractures and seams, along which they form irregular replacement bodies extending laterally into the quartzite and quartz.

The principal ore mineral occurring along fracture planes in the quartz is a black mineral which a polished section of the ore shows to be stromeyerite $(\text{Cu,Ag})_2\text{S}$. In places this is partly oxidized to malachite and black copper oxide (melanconite). Limonite is also present in places. All these minerals are regarded as of supergene origin.

According to reports by several engineers the total proved and possible reserves of the mine amount to 132,125 tons of ore with a tenor of 25 to 35 ounces of silver to the ton.

EXCHEQUER MINE

The Exchequer mine, on the west side of the canyon, is opened by a 1,200-foot tunnel and a 220-foot shaft, mainly on the Exchequer vein, which has produced more than \$3,000,000 in silver, much of it from ore of shipping grade.

For the first 600 feet of the drift westward from the portal the Exchequer vein is separated from the Blue vein by a 30-foot dike of quartz monzonite porphyry. Throughout this part of the mine the vein is 12 feet thick and contained an average width of 10 feet of low-grade ore, which occurred in shoots 2 to 8 feet thick that raked steeply north. There was also high-grade ore in streaks, mainly in a zone 4 feet wide along each wall.

The oxidized ore is very siliceous and resembles that in the Imperial mine. A considerable shipment made by J. W. Walker ran 92 per cent silica.

¹¹Prior, C. E., unpublished report on Exchequer and Imperial mines.

The average of ore reserves with which several engines at the Exchequer mine is as follows:

Proved—31,000 tons of ore containing about 30 ounces of silver to the ton.

Partly proved—34,000 tons of ore containing about 30 ounces of silver to the ton.

In 1919 it was estimated that the ore of the Exchequer mine Imperial could be mined and milled at a cost of about \$60 per ton.

BLUE VEIN

Although the Blue vein has been but little developed, it is said to be nearly as promising as the Exchequer vein. The vein for a width of 8 to 11 feet is said to average 16 ounces of silver and 80 cents in gold to the ton.

TEACUP MINE

The Teacup (Biscuit) mine (No. 1, Figure 1) is $2\frac{1}{2}$ miles west of Cherry Creek, near the top of the range, at an elevation of about 7,800 feet. It is probably on the continuation of the Mother Lode zone, described below. It was worked in 1890 and also in 1907 and 1912 and is said to have produced about \$3,000,000 in silver. It is developed to a depth of 250 feet through a shaft that inclines westward at an angle of about 40° and has many short levels and drifts. The ore follows a tabular sheet of fault gouge beneath a 25-foot thickness of greenish shale interbedded with limestone. The ore occurs in lenticular bodies of white quartz which have replaced the footwall limestone beneath the gouge. According to reports, the valuable ore mineral is either argentite or stromeyerite. The carbonate stains fracture faces in the ore. A width of about 10 feet of good-grade mill ore is reported to be exposed in the bottom of the shaft.

A specimen of dark-gray to blackish ore collected from the dump consists chiefly of replacement quartz of two stages of deposition, with veinlets filling fractures. It is brown, owing to its iron and manganese content, and is more or less calcareous. Most of its dark mineral content is said to be manganese oxide.

MOTHER LODGE

The so-called "Mother Lode," known also as the Teacup lode, is an extensive mineralized zone near the base of the mountain and relatively inaccessible. It follows the contact between the quartzite-shale series on the east and the

overlying blue massive limestone on the west. For the most part it has a limestone footwall and green shale hanging wall, but in a few places two or three feet of limestone occurs on the hanging-wall side. It is said to average about 20 feet in width and to be traceable from a point south of the Teacup mine 12 miles north-northeastward, to the foot of the mountain, where it passes beneath the detritus of Steptoe Valley. Its outcrop is said to be almost continuous throughout this distance. The lode is geologically and mineralogically very similar to that of the Teacup mine, which seems to be a part of it. Like the Teacup lode, it dips westward at medium angles.

The lode is not known to have made much production other than the \$3,000,000 in silver produced by the Teacup mine. In 1919 and 1920 J. W. Walker and associates working on a part of it owned by the Mother Lode Co. crosscut the lode by a 2,000-foot tunnel at a vertical depth of 600 feet. The lode here was found to be 16 feet in width, with an average tenor of \$10 a ton. Several shipments of selected ore carried 57 ounces of silver to the ton and 10 per cent of lead, with a high content of silica and iron.

About one and a half miles (five claim lengths) on the southern part of the lode, extending from the ridge north of the Exchequer mine northward, is owned by the Mother Lode Mining Co., of Philadelphia, Pa., and is being operated under lease by the Liberty Mining Co., of White Plains, N. Y.

Adjoining the Mother Lode property on the north is the Good Chance lead-silver prospect, a group of three claims seven miles north of Cherry Creek, which is being worked with encouraging results by S. T. Stafford and associates. Beyond the Good Chance property some of the remaining six miles of the lode has not been staked, and much of the lode as a whole has been but little prospected.

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THE MINE AND MILLS OF SILVER CITY, NEVADA

By
J. H. HARRIS



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No. 5

BULLETIN OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

THE MINES AND MILLS OF SILVER CITY, NEVADA

By

ALFRED MERRITT SMITH

Mining Engineer, Nevada State Bureau of Mines

PRICE, 20 CENTS



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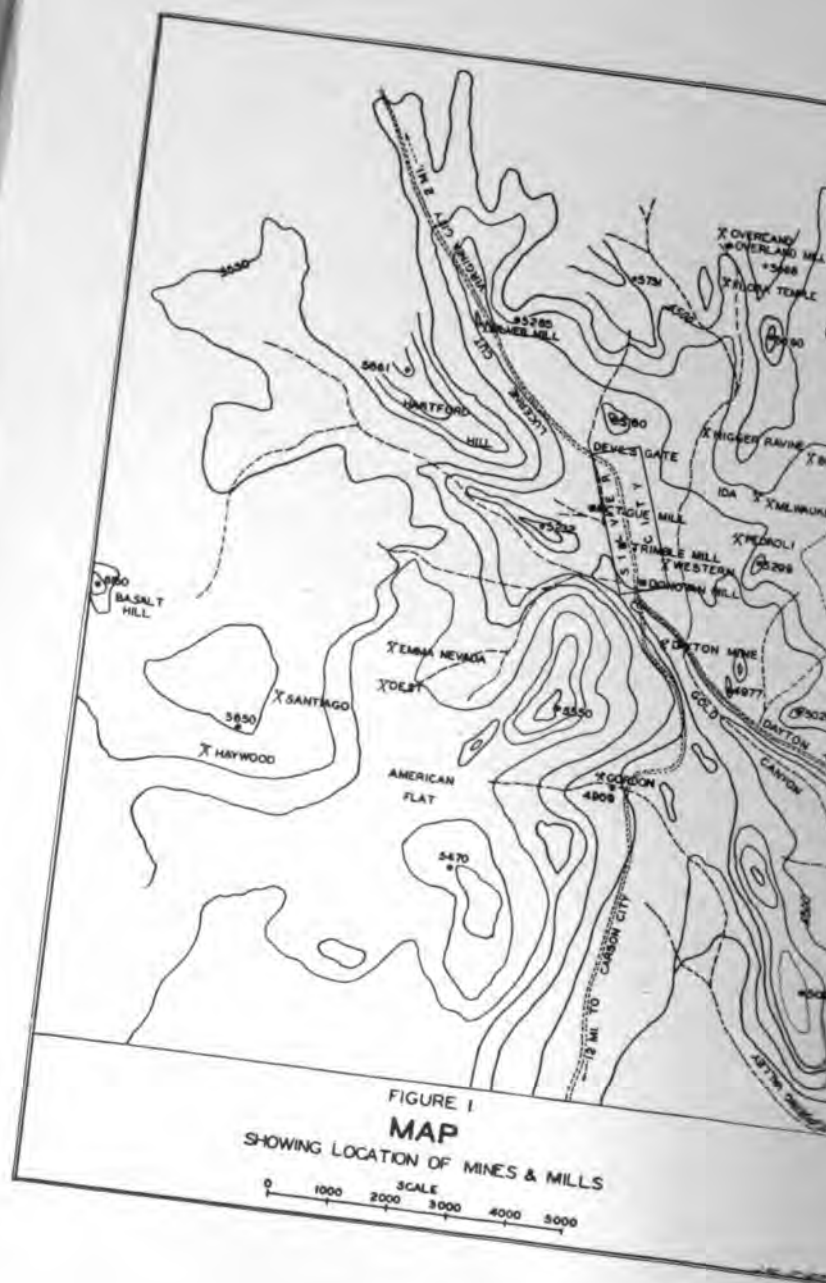
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FOREWORD

Owing to the mining opportunities offered in the Silver City, Nevada, area, the Bureau of Mines is issuing this bulletin so the public may have reliable information on the district, particularly as regards the economic set-up.

The Bureau is planning on issuing a second bulletin which will deal exhaustively with the geologic phase of the problem. It will be several months before the investigation and study of the district for this second bulletin can be finished.

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THE MINES AND MILLS OF SILVER CITY, NEVADA

By ALFRED MERRITT SMITH¹

Second only to Virginia City in the stirring mining annals of the Comstock Lode is Silver City, although overshadowed during pioneer days by its famous neighbor, only two miles north. The continuous stream of gold bullion which flowed from Silver City into the mighty river of silver and gold then emerging from the foot of Mount Davidson caused scarcely a ripple. Very little attention was paid to Silver City then, and the habit of considering it a relatively unimportant adjunct to Virginia City seemingly became fixed. Although the profitable mineral product of Silver City district has continuously been gold, the busy miners did not trouble to change its name.

The mines of Silver City, although in general neither large nor deep, have operated continuously, and the mills there have not ceased running for sixty years. The district apparently refuses to be worked out and for that reason it merits our attention.

MINES

It may seem strange that so little has been written about the mines of Silver City. Few, if any, detailed descriptive articles have appeared in the mining magazines. There are several reasons for this. One, is that for many years it has been a district mined by small operators only. The veins as a rule are small, likewise the ore-shoots, but they are numerous. Another reason is that no large stock companies have existed in Silver City for many years, and the advertising essential to the sale of shares for development has therefore been unnecessary. The various active mines are largely owned by resident individuals, or by small groups who lease to other small groups.

Many of the mining properties consist of only one or two claims, on which are small gold veins, hardly large enough to interest capital looking toward a continuous and long-lived operation. It has been suggested that a consolidation of various interests should be made, whereby one or more large companies could be organized to explore the district at depths not possible to the small operator. Occasional efforts have been made to effect such consolidations, but without success.

Before the completion of the great Sutro drainage tunnel in

¹Alfred Merritt Smith, Mining Engineer, Nevada State Bureau of Mines.

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1878, and for many years afterward, water prevented development in Silver City. Capital avoided what might have been an expensive deep mining where it was presumed the water would run only \$10 to \$20 per ton, which was much less than in the Comstock mines. After the Sutro tunnel had been connected with the Occidental or Brunswick Lode workings, the south lateral had entered the Alta mine, water lessened at Silver City lower levels, and at present most of the water entering is surface seepage of very small volume. A few years ago the Buckeye shaft east of town, 700 feet deep, was pumped. Since then it has refilled very slowly and is not yet dry. In pioneer days an 8-inch pump column and large steam engine were required to keep down the water. When last pumped out by a column and small centrifugal pump unwatered this mine was done so effectively.

Water in the Succor shaft north of Devils Gate is now about to stand at the Sutro Tunnel level, about 800 feet below town level, according to observations made three years ago by the Silver City Mining Company operators.

The evidence shows that water will not now seriously interfere with deep mining. Efficient modern pumps and electric power will easily overcome what was formerly a great obstacle.

Silver City is connected by an excellent highway with Carson City, the State Capital, 12 miles distant. Ten miles of this road, thirty-four miles farther along the same paved road, connects the metropolis of Nevada. The distance to Reno is only 100 miles via Virginia City and the Geiger summit, over excellent roads.

The Sierra Pacific Power Company has branch lines to the properties in the district, from which cheap electric power is obtainable at all leases.

Supplies of all sorts are very reasonable in price. Timber and lumber can be hauled in by truck from Reno at a cost of only a few cents per thousand board feet. Supplies can be shipped over the railroad to Mound House or Virginia City, adjacent to the city. Labor is abundant, reasonable in price, and as good as anywhere. There are excellent schools at Silver City, Virginia City and Dayton. The climate is pleasant, and permits all-year mining and milling operations.

When bullion is obtained from the mills, it can be taken to the United States Assay Office at Carson City, where it can be assayed and bought, thus eliminating express and other charges. Amounts as small as two ounces are received for assay.

At present about 40 men are working in Silver City.

whom are employed in mining and milling, and there is
 edly opportunity for many more. Mining leases may be
 d on reasonable terms, and the chance for success, espe-
 r experienced miners, is excellent.
 s briefly run through a list of the active mines and leases,
 which was visited by an engineer from the State Bureau
 s during April, 1932:

DAYTON

is one of the old mines of the district, which produced sub-
 ly from 1870 to 1875. It has the second deepest shaft
 district (900 feet). Recently Geo. Fuerman and F. W.
 ch have taken a lease and bond and are working through
 el and winze in the upper levels. They have extracted



—Looking south from $\frac{1}{4}$ mile north of Pedrol mine, showing Mil-
 waukee, Pedrol, Dayton and Kossouth mines; Gold Canyon is on
 the left, Carson City highway on right.

erable ore, which is being put through the Trimble mill.
 sees have installed a 500-gallons-per-minute electric pump
 watered the mine to the 220-foot level.

Dayton mine was once owned by F. S. Lacruts, who in 1872
 to W. S. Hobart for \$43,000.

resumption of production by this old property is of interest.
 in is wide, and large bodies of brecciated ore have been
 from it in the past.

EMMA NEVADA

Emma Nevada, lying between the Oest and Santiago, is
 by Mrs. S. Ninnis of Silver City. On March 1 it was
 d to the Trinity Gold Bar Mining Company, of which O. B.

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Lefurgey is general manager and vice president. The new company drove a crosscut from the main tunnel which cut the vein 190 feet below the old workings, and it was reported on May 1, 1932, that ore of milling grade was being extracted.

This mine was located in 1885 and was first operated by Wm. Doidge and H. Piper and is said to have produced \$150,000 or more. It was last worked in 1910. The largest output was made between 1885 and 1890, at which time the Oest and Haywood, adjoining mines, were also producing.

FLORA TEMPLE

During 1931, prior to the management of Chas. Stewart, the Flora Temple mine was very active and productive of a good



Fig. 3—Gordon mine, looking north.

grade of ore. During the summer season over 400 tons were milled at the Donovan plant, and the Trimble mill also ran one lot of 100 tons which netted \$14 per ton, and a second lot of 50 tons of lower grade. This ore was mined and milled during the operation of James Wilson.

The Lager Beer, one of the older mines, is on this vein, and has been productive in recent years.

GORDON

The Gordon mine, formerly known as the Herman Shields property, now owned by Gurney Gordon, Everett Gordon and associates, consists of several claims in the southern part of the district.

The owners are constructing new surface buildings, and are

developing the mine through a main tunnel, working in new ground. The deepest work in this mine was only 100 feet. In June, 1932, five men were employed.

During April one lot of 38 tons of \$50 ore was mined at a depth of 40 feet, and milled at the Trimble mill. The formation consists of metamorphosed volcanics capped by rhyolite. The strike of the vein is about N. 45° E., with a steep dip to the west. The width is from two to six feet. About 12 inches of crushed quartz and clay are exposed for 250 feet along one drift.

On the dump are 1,200 tons of low grade ore which Gordon believes will mill at a profit. This will be sent to the Trimble mill.

HAYWOOD

The Haywood and Santiago mines are owned by the St. Joe Consolidated Mines Corporation, and include 12 patented mining claims. Wm. H. Scott of Dayton, Nevada, is resident agent for the company. The officers of this corporation are Chas. Oster, president, New York; E. S. McCurdy, secretary, San Francisco. Another group with different officials, excepting Chas. Oster who is president, controls the Piedmont Gold Mining Corporation, which owns eight claims on the east side of Silver City district. Three of these claims are known as the Ida group, and five as the Badger group. The St. Joe Mines Corporation also owns control of the Como Mines Company, which owns a large group of claims with much development in the Como district in the Pine Nut range.

During 1931 lessees milled 1,870 tons from the Haywood and Santiago mines, which produced \$14,691, of which 97 per cent was gold. Occasionally the gold tenor of the ore is higher; for instance, in 1929 a lot of 27 tons mined by A. Armstrong and H. Bennetts from the Haywood amalgamated \$2,492.50, 97.7 per cent of the value being in gold.

In 1912 an aerial tramway was built from the mine to the Rock Point mill near Dayton, and the old stamp mill there enlarged and modernized to treat the ore. The Haywood shaft, a two compartment incline, was sunk to the 400-foot level. An expensive modern hoisting, pumping and compressor plant was installed. Unfortunately but little ore was encountered on the lower levels. However, very little systematic development or exploration work was done. A few years later the tramway and other heavy equipment were dismantled and sold.

If drifting north on the Haywood vein toward the principal Comstock fissures and the proven productive vein system had

been persisted in, success would have been assured, success of Hickey, Trimble and Hardwick, lessees the Haywood vein some distance north of the shaft of the trend of ore bodies.

Reports are conflicting as to past production of and Santiago. The best information is to the effect wood had produced \$650,000 and the Santiago \$1,000,000 between 1880 and 1913. The writer was shown a list of b from the Haywood mine, representing 23 small lots between 1884 and 1888, the net results of which over \$90,000.

MILWAUKEE

The Milwaukee mine in Long Canyon is owned by Bennetts, Mike Quilici and S. J. Pedrol of Silver



Fig. 4—Looking west, Milwaukee mine in foreground, I background.

now under option to Hal Bulmer, and associates, or being operated by Harry Bennetts, Raymond B. Armstrong.

In 1930, Harry Bennetts gathered up from the millions of ore which had been rejected as waste by f He had it milled separately and it yielded \$111 amalgamation.

The property is equipped with a 15 hp. General a 15 hp. Westinghouse motor and a two-drill Gar pressor. The formation is so soft that gopher bars but little drilling is necessary.

The vein strikes northeast and dips 60° southeast. The shaft, an incline, is sunk on dip of vein, and is 236 feet deep.

During the winter of 1931, Bulmer had two mill runs, totaling about 100 tons, one of which yielded nearly \$40 per ton. Afterward a lessee, Geo. Wilson, produced 21 tons which yielded \$25 per ton. The Bennetts and Armstrong are mining good ore on the 236-foot level, and in June, 1932, another mill run was nearly ready. Additional ore has been developed on this level, and the mine is in excellent condition.

MONTEZUMA

The Montezuma mine, formerly owned by Manuel King of Dayton, Nevada, produced, in the nineties, some shipments of very rich gold ore from near the surface. The ore was mined from several places, in a series of three or more veins having a strike of about N. 60° E. The most southerly vein, which was the principal one mined, is from two to three feet wide, and has a nearly vertical dip.

Recently King optioned the mine to Dr. John W. Ross, who organized the Montezuma Gold Mines Company, Ltd., of which Dr. Ross is president, Irvin R. Hall, vice president, Guy L. Bliss, secretary-treasurer, all of Long Beach, California.

The engineer in charge of the work is Clarence Enrich, formerly of Globe, Arizona. The company began work in October, 1931, and has spent at least \$5,000 on new equipment, consisting of hoist, headframe, a two-drill compressor and buildings. The plan is to immediately sink 300 feet, and at 50-foot intervals to crosscut to the vein. It is also intended to drift east along the vein to its intersection with a strong fissure having a strike of N. 10° W. and dipping 46° NE. Some ore in past years has been taken from this intersection near the surface. Electric power will be supplied by the Sierra Pacific Power Company.

NIGGER RAVINE MINE

Formerly owned by Governor Stevenson, the Nigger Ravine is now owned by Fred and Harry Bennetts, who have installed a hoist and sunk a 65-foot shaft. At present they are operating the Milwaukee mine, and the Nigger Ravine is idle. These owners have declined offers to lease Nigger Ravine, intending to resume work there soon.

OEST

The Oest mine is situated about one-half mile west of Silver City. It is reputed to have had an early-day production in excess of \$1,000,000, but it is doubtful if records can be discovered that

will substantiate the sum. That it produced much well known, and a gold ore exhibit which won a Chicago World's Fair in 1890 came from this mine.

In 1921 the seven claims comprising the Oest, or



Fig. 5—Vein two feet wide at Montezuma mine.

were acquired by a company headed by Leon M. Hall. A surface plant, including electric power, 100 hp. hoist, and air compressor, was installed to replace the old steam engine. The new equipment is still intact. Ore ranging from 10 to 20 per ton was shipped to the McTigue mill.

Upon the death of Hall the company disintegrated. The property went to the Republic Bond and Mortgage Company of Los Angeles, and about two years ago was acquired by A. R. Bowen, of Redlands, California.

A. R. Bowen, and C. E. Bowen, manager, state that they will resume work soon. Hall retimbered various old workings and at the time of his death had about 100 tons of fair grade ore in sight in the north drift on the 200-foot level. The vertical shaft is 15 feet deep but no lateral development was done from the bottom of the shaft. Excepting one small lot, no ore has been mined from below the 200-foot level. The mine is on the Comet



Fig. 6—Overland 10-stamp mill.

fault, near the northerly extension of the Haywood fault. The vein trends northeast and dips southeast.

OVERLAND

Alex R. Dixon and Frank Gordon are leasing at the Overland mine, and have sent ore to the Donovan mill recently, one lot of 60 tons yielding \$16 per ton.

Mr. Jos. Greuse of Silver City is also leasing at the Overland, and treats his ore at the Overland mill, a 10-stamp amalgamating plant, which was running intermittently on the lessee's ore in June, 1932.

A block on the Overland vein is leased to Steven Briginti and three associates, who in April, 1932, completed a successful mill run.

The Overland mine and mill is owned by the Comstock Silver

Mines Co.; Frank Manson, well known Nevada miner, is president of the company.

PEDROLI

Shown on the old maps as the Milk Ranch, one fourth of town, this mine is now owned by S. J. Pedroli and of Dayton, Nevada.

M. Quilici began mining here in 1895 and opened a mine from which, mining alone, he states he extracted \$10,000 in 10 days. Each year since then the owners have worked the mine, and the mine has yielded many thousands of dollars. In 1931 three shipments were made to the Trimble mill, netting \$1,100. Since then another shipment has been made. The mine is equipped with a new 30 horsepower Fairbanks hoist, three 50-KVA Westinghouse transformers and surface buildings. The shaft is a two-compartment incline, only 60 feet. At present, work is being conducted in the old 700-foot tunnel. The main vein strikes NW. and dips 75° E.

The Milwaukee and Ida mines to the northwest of the Ranch are probably on the same vein. Going northerly, a coarse-grained micaandesite dike, locally termed the "dike". Smaller veins cross E. and W., and at their junction both dike and main vein profitable ore has been mined. The mine produced heavily when operated by the Nevada Reduction Company of Dayton between 1902 and 1905, keeping the mine in steady operation.

Chester Kenny and Everett Kenny of Silver City operate on the southern part of the Pedroli group, where they are mining NW. from the bottom of an 80-foot shaft. They are extracting ore and will soon have a mill shipment ready. In the summer of 1931 they sent one substantial lot to the mill.

SANTIAGO

The Santiago mine is one of the Haywood group, owned by St. Joe Consolidated Mines Corporation, previously operated by Wm. H. Scott of Dayton is resident agent.

The Santiago vein is the northeastern extension of the Haywood vein. It has a strike of N. 75° E., and dips 50° E. to a depth of 60 feet. The footwall is metaandesite and the hanging wall at depth is tertiary andesite breccia, while from the surface to a depth of 60 feet or more it is conglomerate composed of angular and rounded fragments. All of this conglomerate material derived from the erosion from the footwall.

ises steeply, forming a high hill to the northwest. This condition suggests relatively late faulting, with erosion carrying the conglomerate material across the vein and depositing it at the foot of the scarp.

In December, 1931, R. A. Trimble, Luke Hardwick and Jack Hickey, leasing on the Santiago, opened up a new ore shoot near the surface, 8 to 11 feet wide. From this shoot two men, occasionally three men, have since steadily mined 300 tons per month which yielded from \$8 to \$12 per ton. The ore is a soft, brown, altered breccia containing some quartz. Most holes for blasting are made with gopher bars. The ore is dropped down a winze to a tunnel which emerges near the Oest mine, whence it is trucked to the Trimble mill for 50 cents per ton. Stulls only are used in timbering, as the ground is dry and stands well. These lessees are conducting a very profitable operation.

SILVER HILL

Delbert Davis and son are the principal lessees on this well-known mine. Their work has been quite successful, and at present they are working in the upper levels and hoisting through the main shaft.

Several other leases, all of which are at present in ore, are operating on claims owned by the Silver Hill Mining Company. In all, twelve men are employed at the mine.

According to Mr. Wm. Donovan, manager of the Silver Hill Mining Company, it was originally incorporated by Mackay and Fair, famous Comstock Lode operators. Mackay and Fair sank a vertical shaft and incline to a vertical depth of 1,300 feet. The original 50-year incorporation charter issued to the Silver Hill Mining Company expired seven years ago, and was renewed at that time. The present officers are C. A. Torello, president, and A. V. Fisher, secretary, both of San Francisco.

In July, 1932, ore was being stoped on the 220-foot level, and some filling from old stopes beneath Lucerne cut was also being extracted and milled. Lucerne cut, shown on the U. S. Geological Survey map made by George F. Becker in 1881, is a great open pit from which a great quantity of ore has been taken. Between 1899 and 1906 records show that 60,000 tons were mined from Lucerne cut which milled \$4.68 per ton at the Rock Point mill at Dayton on the Carson River. Prior to this there is no record of what was mined from the pit, but the production was undoubtedly large.

Mr. Donovan states that the present grade of ore from Hill mine averages about \$10 per ton. It is easily mined but little blasting is necessary. The ground stands



Fig. 7—Lager Beer vein and mine.

timbers are necessary. A profit is said to be made on ore assaying above \$4 per ton.

SPEARHEAD

The Spearhead mine is located about half a mile north of Silver City. Charles A. Finney, long-time resident of Silver City, has a two-year lease on the Spearhead from Dave Maltman.

to buy this property, which was formerly owned by the Silver City Mines Company. Finney reports excellent results in 1932. About April 1, 1932, a shipment of 40 tons to the mill yielded \$35 per ton.

McKinney, who is leasing on the Lager Beer claim of the head group, has a shipment of 35 tons ready for the mill.

WESTERN MINE

located on the eastern edge of Silver City, adjacent to the Western mine, this mine is owned by Mrs. Lena Armstrong. It consists of one standard lode claim, and is leased for a period of 10 years to D. B. Williams, Harry Taunt, and Geo. Cose. In May, 1932, the lessees took out 30 tons of \$10 ore, which was milled at the Trimble mill.

ESTIMATED PRODUCTION OF THE SILVER CITY DISTRICT

It is impossible to secure accurate figures giving the total past production of the mines of Silver City district. The following figures were prepared about 20 years ago by mining engineers and geologists operating there, and should be regarded only as approximate data obtained from miscellaneous sources:

Alta.....	\$750,000
Justice.....	5,000,000
Lucerne.....	1,000,000
Hartford.....	750,000
Snell (Olympia).....	250,000
St. Louis.....	100,000
Silver Leaf.....	20,000
Golden.....	250,000
Regent.....	100,000
Dayton.....	1,000,000
Kossuth.....	20,000
Spring Valley.....	75,000
Columbia.....	50,000
Succor.....	1,000,000
Holman.....	1,000,000
Overland.....	750,000
Umatilla.....	150,000
Badger.....	35,000
Hard Luck.....	10,000
Burrier.....	15,000
Cook & Gray.....	200,000
Allen.....	120,000

Lager Beer.....	\$240,00
Flora Temple.....	120,00
Silver Hill.....	1,000,00
Piedmont.....	50,00
Vivian.....	600,00
Midas.....	40,00
Pioneer.....	300,00
Grass Widow.....	115,00
Lucky Star and Morning Star.....	30,00
Cosmopolitan.....	150,00
Underground.....	90,00
Silver City Flat.....	75,00
Ida.....	98,00
Milwaukee.....	160,00
Pedroli.....	50,00
Buckeye.....	1,500,00
Smith.....	40,00
Watson.....	25,00
Mt. Bullion.....	20,00
Lanzac and Northern Belle.....	250,00
Golden Eagle, etc.....	30,00
Comet North Extension.....	10,00
Pansy.....	10,00
Red Jacket.....	35,00
Calhoun.....	20,00
Independent.....	300,00
Oest.....	750,00
Boston and Lester.....	140,00
Comet.....	20,00
Santiago.....	1,000,00
Haywood.....	650,00
Harris Claim.....	15,00
Miscellaneous Pits.....	50,00
Cyanide Plants.....	900,00
Total, \$21,528,000	

MILLS

small stamp mills operate continuously in Silver City. The first stamp mill was built in 1900 by R. A. Trimble and Nate Trimble. At first it consisted of but five stamps. Later on two



Fig. 8—R. A. Trimble, exhibiting a bar of gold bullion produced from a lessee's mill run.

up batteries were added, an increase to 13 stamps. It is an amalgamating plant, and the process has never been changed. The ore is very easy to treat by old methods. The stamps weigh 900 pounds each, the drop is six inches,

mesh of screen thirty-five, height of discharge. Amalgamation is both inside the mortar and outside plates. Capacity is about three tons per stamp per hour which could be greatly increased if necessary, as usually a soft, granular, altered andesite, containing crushed quartz. It has been found that the best results are obtained by not putting the ore through silver amalgamating pans six feet in diameter and ten half feet deep, obtained from defunct Virginia City, are used as amalgam and quicksilver traps, one pan to battery.

The grade of ores treated ranges from \$4.50 to \$10, the average being about \$10. Trimble built and owned



Fig. 9—McTigue stamp mill.

pioneer cyanide leaching plant just below Silver City. The mill has put out \$250,000 in bullion between 1902 and 1910. The charges for custom ore average \$2 per ton. The tailings are in value from \$1 to about \$4 per ton, depending on the character of the ore milled, flow by gravity to the cyanide plant a few hundred feet south. These stamps are purchased according to a graduated scale based on value, the average price range being from 20 cents to \$1 per ton.

Adjoining the cyanide plant is the Donovan 10-stamp mill. Here 1100-pound stamps are used, and the amalgamating methods are the same as those at the Trimble mill. Ores are received by the Donovan mill, but recently the

almost exclusively on Silver Hill mine ore. The mill was built by F. S. Lacruts in 1890 and has been in fairly continuous operation for 42 years, and the cyanide annex has been in operation for 30 years.

The McTigue mill is located on the northwestern limit of Silver City and consists of 15 stamps weighing 800 pounds each and equipped with copper-plate amalgamation equipment. This mill treats ores and has been in operation for 32 years.

The Overland is a ten-stamp amalgamation plant built a few years ago at the Overland mine. It is powered by electricity and operated intermittently. At present it is being used by lessees of the Overland mine.

The first cyanide plant in Silver City was built by the late



Fig. 10—Donovan tailings ponds, drying ground and derrick at cyanide plant.

Dr. R. D. Jackson, one time Dean of the University of Nevada School of Mines prior to the founding of the well-known University School of Mines. In 1900 Jackson formed a partnership with J. Warne Phillips, who resigned from the chair of Geology and Chemistry at the University of Nevada to engage in mining and milling with Prof. Jackson at Silver City. A few years later Phillips bought out Jackson, and after a time sold to John Donovan, Sr., father of the present owner. Dr. Phillips designed and installed the huge tailings derrick, the outstanding feature of the plant.

At the Donovan plant a partial separation of slime is made by washing the sand in small ponds and draining off the slime from

the top. The separated slime is treated in a small v
tion plant. The sand, containing much slime, is ren
the ponds by a clamshell dredge bucket operated
derrick having a very long boom. This wet tailing
upon a drying ground by the derrick, and after air-d
what it is spread out over the drying ground by ho
wheeled scrapers, thoroughly plowed and disc-har
finally charged into a series of five redwood leaching
five feet deep and twenty feet in diameter. A small
pulverent well-slaked lime is mixed with the sand be
ing the vats. A five-pound-per-ton sodium cyanide
first used for leaching, which is followed by a two-pou
and a water wash. Precipitation is effected by zinc
wooden boxes. Excelsior (shavings of shredded wood
the bottom compartments of the boxes to prevent
precipitate passing over. In cleaning up, the zinc is v
returned to the boxes; the precipitate is filtered o
over a small cleanup tank, and is dried and melted with
preparation. The resulting cyanide bullion is very pur
ages 500 gold fine and 400 silver fine, which is abo
ounce in gold and 12 cents per ounce in silver.

Such splendid results with the old McArthur-Forr
proves the ease with which the ores may be cyanided.

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A bulletin setting forth the economic possibilities of the district.

Nonmetallic Minerals in Nevada, by J. A. Fulton and A. Merritt Smith, 1932.....

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BULLETIN OF NEVADA STATE BUREAU OF MINES AND
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METAL AND NONMETAL OCCURRENCES IN NEVADA

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FOREWORD

This bulletin is supplemental to that part of United States Geological Survey Bulletin No. 507 which deals with Nevada, to which has been added a section listing the nonmetal occurrences. The bibliography of the mining districts listed in Bulletin 507 is complete to 1912. In this bulletin the bibliography of the districts listed in Bulletin 507 covers the period between 1912 and 1916, so that references prior to 1912 must be looked for in Bulletin 507. The data were compiled by the United States Geological Survey. Mr. Carl Stoddard of the State Bureau of Mines assisted in the compilation, located the mining districts on the map, wrote the introduction, drawing freely on those parts of the United States Geological Survey Bulletin 507 that were applicable, and added foot notes.

It is interesting to note that the present compilation includes twice as many Nevada mining districts as Bulletin 507, and that the State is now extensively producing tungsten, quick-lime, aluminum silicate for refractories, and bentonitic clays—which were unimportant items prior to about 1916.



METAL AND NONMETAL OCCURRENCES IN NEVADA

PART I—INTRODUCTION

By CARL STODDARD

ORIGIN AND SCOPE OF THE WORK

The mining districts of the western United States were catalogued and maps prepared showing the location of the districts and the dominant metals by Mr. J. M. Hill in 1910. The work was published as United States Geological Survey Bulletin No. 507 in 1911.

In 1931 the United States Geological Survey made a new compilation of the mining districts in Nevada along the same general lines followed in Bulletin 507, but added a section on non-metallic occurrences. The Nevada State Bureau of Mines contributed its data to the compilation and issued this bulletin.

Many of the localities catalogued and mapped are not mining districts in the strict legal sense or use of the term. Mining districts were created and sanctioned by law primarily for the convenience of recording the mining claims. In the early stages of development of mining in the West, transportation was slow and costly. In order to eliminate the long journeys to county seats, mining districts were organized to provide local facilities for mining.

Modern transportation has largely removed these conditions, and organized mining districts are now seldom created at new discoveries. A new discovery is merely given a name, and that name serves for its identification indefinitely.

The term "Mining District" is used in this bulletin in the broader sense; it applies to the localities where metallic ores have been mined in sufficient quantities to be worthy of note. Some localities were excluded from the list because of the lack of definite knowledge concerning them.

DISTRIBUTION OF DISTRICTS

Of the seventeen counties of the State are producers. Nye County, the largest, leads in the number of districts, while Storey, with its Comstock district, the site of the first lode mining in the State, comes last. In this connection it is interesting to note a comment made by the Curator of the State Museum in his

report to the State Legislature of 1881, as follows: be useless to disguise the fact that confidence in the lode, heretofore considered the backbone of mining in Nevada, has greatly diminished. Attention is being turned to other mineral veins, almost everywhere in the State, and it is those who think that, even if the Comstock strike, Nevada will still be for an indefinite period conspicuous for its great wealth of resource in precious metals."

A glance at the map shows some blank areas. In these areas the geologic structure of the mountains is unfavorable for mineral deposition. In northern Washoe and northern Humboldt Counties the mountains are composed of late Tertiary basaltic lava flows, with the broad valleys between covered by Quaternary alluvium. These lavas have not been subjected to any mineralizing agencies since their emplacement.

The nearly blank areas in parts of Clark and Lincoln Counties cover regions where the rocks are flat-lying Paleozoic and are undisturbed by igneous intrusions.

In northeastern Nye County is another lean area. This region is characterized by high, rather narrow, mountain ranges separated by broad desert valleys. The rocks are for the most part Paleozoic sediments with granitic intrusions, and few volcanics. The scarcity of mining districts here is due not to unfavorable formations, but to the isolation and relative inaccessibility of the region, together with the fact that the average Nevada prospector is partial to regions where volcanics predominate.

FORM AND CONTENT OF DEPOSITS

The following description of the form and content of the deposits is by Waldemar Lindgren, in U. S. Geological Survey Bulletin 507:

FORM AND CONTENT

The form of the deposits is manifold and depends on the spaces provided for their reception or on the manner in which they made place for themselves. Practically all of them were formed by deposition from water solutions, usually ascending hot water, and as the pressure of such waters commonly follows fissures the resulting deposits are in large part fissure veins. The walls of the fissures were soaked by the solutions and ores were deposited in them. Some rocks like limestone are particularly susceptible to chemical alteration, and where altering such rocks the mineralizing solutions spread

d wide, causing the deposition of metallic ores. Such currences are called replacement deposits.

The ore minerals were in the first place sulphides of the baser metals, such as galena, pyrite, or zinc blende, more rarely oxides such as magnetite. Gold alone has originally been deposited as native metal; more rarely it is combined with tellurium. Through the oxygen of surface waters the sulphides have usually been oxidized into various other compounds such as cerusite, hematite, and calamine; this so-called oxidized zone ordinarily reaches down to the permanent water level and in some places considerably below it. In regions of heavy precipitation the oxidized zone is thin. Where there is little rainfall the water level lies far below the surface. Within the Cordilleran region the water level is rarely more than a few hundred feet below the surface; in exceptional places such as Tintic, Utah, it may exceed 200 feet in depth.

The ores of the oxidized zone are, as a rule, richer than the underlying sulphides. Just below the oxidized zone secondary sulphides may be formed through concentration by descending surface waters, and this part of the deposit is likely to be exceptionally rich. Such secondary sulphides are chalcocite or copper glance and various rich silver minerals. In many copper deposits, such as those at Ely, Nevada, and Miami and Ray, Arizona, the only workable part of the deposits consists of a layer of this secondary copper glance.¹ In silver veins such sharp division between the two zones is found. Much of the richest ore mined near the surface in the Cordilleran region is the result of secondary enrichment by descending waters.

CLASSIFICATION OF DEPOSITS

PRE-CAMBRIAN

In assigning an age to an ore deposit, the first division line is the beginning of the Paleozoic era, with the Cambrian period. Ores older than that period are called pre-Cambrian, and those that are younger post-Cambrian.

In Nevada there is only one known deposit that is of pre-Cambrian age. In the Copper King district, Clark County, a

ever, it is interesting to note that as a result of recent intensive geology, followed by drilling, in the Ely district, great quantities of workable secondary copper sulphides (chalcopyrite) have been proven to underlie the primary sulphides in the district.

pre-Cambrian basic dike carries some copper, platinum. In Nevada pre-Cambrian areas are small and limited and the Copper King occurrence is the only one which is assigned to that age.

POST-CAMBRIAN

In Nevada the marked difference in the character of occurrence of ore deposits of Tertiary age, and those older, is such that the distinction is often made by classifying them as either Tertiary or pre-Tertiary deposits.

The pre-Tertiary ores are most abundantly associated with Paleozoic, and Triassic and Jurassic sedimentaries, though in nearly all cases ranging from late Jurassic to late Cretaceous. They were for the most part formed during the great igneous intrusions which invaded the region at that time. Most of the copper, lead, and zinc mines of the State belong in this class.

The ores of Tertiary age in Nevada are nearly all associated with extrusive igneous rocks, and contain principally gold and silver, either separately or together. The Tertiary period was one of great volcanic activity, especially in the southwestern parts of the State. The fracturing and brecciation of the rocks, concomitant with the volcanism, provided a means for ascending hot waters and vapors which deposited minerals in the fissures or soaked into the walls, forming ore. Such metallization of the wall rocks, filling of crevices, and partial replacement of fragments of rock, created the various types of veins. The deformation of the rock by shearing and crushing, "shear zones" or "shear veins," like the Packard vein in the Eureka district. Shattering and crushing created zones of brecciated veins, of which the Jackson vein of Gold Butte is an example. A stockwork is a mass of rock that has been completely fractured, with "stringers" or seams of ore in the fractures which strike in all directions, creating a network of veins. The usual procedure in mining such deposits is by the "cave" or "hole" method, as at the Flowery Mine at Virginia City.

A fissure vein forms in a major fracture, or "fissure," which is roughly tabular in shape, and contains "shoots," "dikes," "pipes" or "lenses" of ore, like the Comstock lode, Virginia City, or the Coalition vein at Seven Troughs.

The above types of veins may occur in either igneous or sedimentary rocks, the former being more common in Nevada. It is the deformation of the country rock and the solfatara accompanying volcanism, that are the controlling factors in the formation of these types of veins.

placement deposits are formed by the chemical action of circulating waters upon the enclosing rocks. Limestone, being most susceptible to chemical action, contains most of the deposits of this type. The metallizing solutions dissolve the limestone and deposit metallic minerals; thus an exchange or replacement takes place. The lead ores at Eureka, Nevada, were formed in this manner.

Contact metamorphic deposits are formed at great depth where masses of liquid or viscous magma come in contact with the enclosing rocks, which are changed or "metamorphosed" by the heat and vapors rising from the magma. Limestone is often changed to garnet or epidote, and metallic minerals are at times produced in sufficient quantity to form ore deposits. The copper deposits at Yerington and the tungsten veins at Mill City, Nevada, are contact metamorphic deposits.

GEOLOGY

The record of the geologic history of Nevada begins with the rocks of the pre-Cambrian basement, which are exposed only in the extreme southern part of the State. Here the Colorado River and its tributaries have cut through the overlying Paleozoic rocks into pre-Cambrian schists and gneisses.

Ore deposits of present economic importance have been found only in the rather limited known areas where these rocks are exposed.

During the Paleozoic era the eastern two-thirds of the State was submerged at times beneath the Paleozoic seas, and the sediments laid down totaled thousands of feet in thickness. Western Nevada was a land mass. Early in the Triassic period the situation became reversed, and throughout Triassic and Jurassic times western Nevada was submerged beneath the waters of the sea, while the eastern Nevada land mass furnished the material for the 10,000 feet or more of sediments laid down in the Mesozoic sea. With the close of the Jurassic, the Great Basin comprising all of Nevada and parts of adjoining States, was elevated approximately to its present height, marking the beginning of the general physiographic features that characterize the State today.

A great intrusion of granitic rocks, accompanied by faulting and folding of the Paleozoic and Mesozoic sedimentary rocks, resulted in the formation of numerous mountain ranges traversing the State from north to south.

Uplift and erosion, with its attendant faulting, continued throughout

all Tertiary time, especially during the Miocene epoch great quantities of lava rocks, andesite, rhyolite, dacite and latite were extruded. Many of the great gold and silver deposits of Nevada were formed at this time. At the close of the Tertiary, extensive faulting reelevated and tilted the Sierra Nevada and desert ranges into their present attitudes.

Tertiary sedimentary rocks are relatively few, and are of little economic importance. Some of the thin beds of shales and sandstones in Elko and Eureka Counties are presumably of Tertiary age, and are tentatively correlated with the Green River series of the Uinta Basin. The oil shales of Elko County and the sandstone beds of Eureka County are members of this series. The boldt beds of eastern Nevada (Pliocene), the Truckee beds of central Nevada (Pliocene), and the Esmeralda formation (Miocene) of southwestern Nevada consist of unconsolidated sandstone and diatomaceous earth. They occupy marginal positions at the bases of the mountain ranges, and probably underlie the alluvium in the valley floors. In some localities the Esmeralda formation has been elevated by faulting to positions higher than the present valleys.

Tungsten has become an important factor of the mining industry in Nevada. The mineral scheelite (tungstate of lime) has been found in many localities. It is mined in contact metamorphic deposits at Mill City, Nightingale, Ragged Top, Osceola, and Silver Dyke. Nevada now ranks first in tungsten production in the United States.

Recent high prices of quicksilver gave an added impetus to the search for that metal, and many new discoveries were made. Nearly every county in the State is a potential producer of mercury. It is found in nearly all the Tertiary igneous rocks and the older sedimentaries. The principal producing mines are near Lovelock, Virginia City, Montgomery and Mina. At Lovelock and Mina the ores occur in limestone, at Virginia City in andesite, and at Montgomery in quartzite. In the Ivanpah district, Elko County, quicksilver mines are being developed in the granite.
lite.

The prevailing low price of metals has caused the prospector and miner to turn their attention to placer mining. Dry washing the gravels in shallow gulches and ravines at favorable seasons is now being done in many parts of the State. Hydraulic mining at Round Mountain has continued seasonally since 1915. The Virgin Canyon in Lander County, Tuscarora in Elko County, and the Indian Canyon in Pershing County were heavy producers of gold in the past.

Viewed as a whole, Nevada presents a panorama of range after range of mountains, trending northerly and southerly, separated by desert valleys. The mountains are built of faulted and folded Paleozoic and Mesozoic sedimentary rocks, intruded by granite, and liberally plastered with Tertiary lavas. Thus the forces of nature, operating through the ages, have prepared the field, plowed huge furrows, and planted and matured a crop of precious and useful metals for man to harvest.

A statement of the geologic formation of the region gives a general idea of the rocks in which the deposits occur. An attempt has been made to name the oldest rocks first, using the terms pre-Cambrian schists, granite, or complex. The term complex is used in districts where schist, gneiss, and granite are found in intimate association. The Paleozoic or Mesozoic igneous stones, slates, quartzites, etc., are all combined under the term Paleozoic or Mesozoic sediments. Intrusive rocks are said to "cut" the older formations, and volcanic flows "cap" the older formations. Where the relation is not known only the names of the rocks are given, as Paleozoic sediments, granite, and so on.

The kind of deposits found in the region are noted. No attempt has been made to discuss the deposits; simply their general character is mentioned in the belief that it may be of use. The following terms are used with the meanings indicated, which are sanctioned by the United States Geological Survey:

Vein—A single body of minerals occupying or following a fracture, the walls of which generally, though not invariably, are well defined. Where several veins are so closely spaced that the ground between them becomes in places ore bearing and the whole width constitutes an ore body the assemblage is called a lode. In this bulletin the term vein is used for both veins and lodes.

Contact-metamorphic deposits—Ore deposits which occur near the contacts of intrusive rocks with sedimentary beds which carry minerals characteristic of contact metamorphism, such as garnet, pyroxene, and epidote.

Replacement deposits—Masses of ore and gangue formed by the alteration of limestone, dolomite, and other rocks. Usually irregular in form and in many places grading into country rock.

Disseminated deposits—Deposits containing ore minerals scattered throughout the rock, such as chalcocite occurring in granite through granite porphyry. The term "impregnations" is sometimes applied to deposits of this type.

Stockwork—A deposit consisting of a complex system of fissure veins.

Lenses—Ore bodies that are more or less elliptical in cross-section, thickest at the center and thinning out toward the edges, tabular in shape.

To all of which is added a bibliography of United States Geological Survey publications relative to the district.

NEVADA BULLETIN
4, PLATE 1.

in preparation. Report
S. G. S. Carson Sink topographic map.

DISTRIBUTION OF THE PREDOMINANT METALS PRODUCED IN THE MINING DISTRICTS OF NEVADA

County	Gold	Silver	Copper	Lead	Zinc	Iron	Manganese	Quick-silver	Tungsten	Antimony	Radium	Nickel	Unknown	Total
Churchill	11	7	2	2	1	1	1	1	1	1	2	1	1	25
Clark	6	1	2	2	1	1	1	1	1	1	1	1	1	17
Douglas	5	1	2	1	1	1	1	1	1	1	1	1	1	7
Elko	34	2	11	1	1	1	1	1	1	1	1	1	1	40
Esmeralda	16	7	1	1	1	1	1	1	1	1	1	1	1	25
Eureka	2	7	1	1	1	1	1	1	1	1	1	1	1	13
Humboldt	13	3	2	2	1	1	2	1	1	1	1	1	1	23
Lander	9	4	2	3	1	1	1	1	1	1	1	1	1	16
Lincoln	6	4	1	1	1	1	1	1	1	1	1	1	1	18
Lyon	5	3	1	1	1	1	1	1	1	1	1	1	1	8
Mineral	13	1	3	1	1	1	1	1	1	1	1	1	1	23
Nye	30	16	2	1	1	1	1	3	1	1	1	1	1	49
Ormsby	1	1	1	1	1	1	1	1	1	1	1	1	1	8
Pershing	10	12	1	3	1	1	1	2	5	1	1	1	1	34
Storey	1	1	1	2	1	1	1	1	1	1	1	1	1	2
Washoe	7	4	1	5	1	1	1	1	3	1	1	1	1	21
White Pine	7	1	1	1	1	1	1	1	1	1	1	1	1	21
Totals	157	79	32	28	3	3	7	10	11	2	2	1	1	336

CHURCHILL COUNTY—Continued.

- Au, Ag, Sb.
 miles ENE. Fallon, 60 miles SE. Lovelock, S. P. R. R.
 imentary rocks.
 ns.
 rader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
 United States: U. S. Geol. Survey Bull. 624, pp. 194, 199, 1917.
 eoln, Francis Church, Mining districts and mineral resources of Nevada,
 p. 1, 1923.
 rader, F. C., Mining districts in the Carson Sink region, Nevada: Report
 in preparation.
 S. G. S. Carson Sink topographic map.
Hills (Quartz Mountain). Ag, Pb, Au.
 miles by road SE. Fallon, S. P. R. R.; 16 miles SE. Lincoln Highway at
 West Gate. Extends into Mineral and Nye Counties.
 eanic tuff capped by basalt and underlain by andesite.
 ns.
 eoln, Francis Church, Mining districts and mineral resources of Nevada,
 p. 2, 1923.
 rader, F. C., Mining districts in the Carson Sink region, Nevada: Report
 in preparation.
 n. Res. 1922, pt. 1, p. 319.
 1923, pt. 1, p. 493.
 1924, pt. 1, p. 430.
 1925, pt. 1, p. 675.
 1926, pt. 1, p. 529.
 1929, pt. 1, p. 651.
 S. G. S. Carson Sink topographic map.
Vista. Fe. (See Mineral Basin, Pershing County.)
 uthern extremity 25 miles SE. Lovelock, S. P. R. R.
 assic sedimentary rocks cut by granite intrusives and covered in part by
 Tertiary volcanic rocks and Quaternary sediments and wash.
 rader, F. C., Buena Vista iron deposits in Pershing and Churchill Coun-
 ties, Nevada: Report in preparation for publication by Nevada State
 Bureau of Mines.
 S. G. S. Carson Sink topographic map.
Mountain. Pb, Ag
 miles ESE. Fallon, S. P. R. R.
 assic (?) limestone.
 ns, replacements.
 rader, F. C., The Chalk Mountain, Quartz Mountain, Gold Basin, and
 King mining districts, Nevada: U. S. Geol. Survey P. N. 17276, Sep-
 tember 15, 1927.
 S. G. S. Carson Sink topographic map.
Kettle. Cu.
 Grimes Canyon, W. slope Stillwater Range.
 orite, overlain by altered porphyry.
 ns.
 eoln, Francis Church, Mining districts and mineral resources of Nevada,
 p. 2, 1923.
 n. Res. 1929, pt. 1, p. 651.
 S. G. S. Carson Sink topographic map.
(White Plains). Au.
 miles SW. White Plains (Huxley Station), S. P. R. R.
 h free gold ore in hematite gangue.

CHURCHILL COUNTY—Continued.

Desert (White Plains)—Continued.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 2-3, 1923.

Min. Res. 1928, pt. 1, p. 454.

U. S. G. S. Carson Sink topographic map.

Eagleville (Hot Springs). Au, Ag (barite).

64 miles SE. Fallon, S. P. R. R.

Volcanic tuff capped by basalt and underlain by andesite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 3-4, 1923.

Min. Res. 1924, pt. 1, p. 431.

1928, pt. 1, pp. 454-455.

1929, pt. 1, p. 651.

U. S. G. S. Carson Sink topographic map.

Eastgate. Au, Ag, Pb.

60 miles ESE. Fallon, S. P. R. R., on W. slope Desotoya Range.

Broken formation of quartz and talc.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 4, 1923.

U. S. G. S. Carson Sink topographic map.

Fairview. Ag, Au, Pb, Cu.

35 miles in airline SE. Fallon, S. P. R. R.; 2 miles S. Lincoln Highway.
Mesozoic sediments overlain by Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, pp. 190, 191, 194,
198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 4, 1923.

Schrader, F. C., Mining districts in the Carson Sink region: Report
ration.

Min. Res. 1922, pt. 1, p. 319.

1923, pt. 1, p. 494.

1924, pt. 1, p. 430.

1925, pt. 1, p. 675.

1926, pt. 1, p. 530.

1928, pt. 1, pp. 454-455.

1929, pt. 1, p. 651.

U. S. G. S. Carson Sink topographic map.

Fireball. Au.

23 miles NE. Fernley, S. P. R. R.

Nevada has new gold find: Eng. and Min. Jour., vol. 132, No. 1, p.
13, 1931.

U. S. G. S. Wadsworth topographic map.

Gold Basin. Au, Ag.

45 miles SE. Fallon, S. P. R. R.

Tertiary volcanics, quartz-latite predominating.

CHURCHILL COUNTY—Continued.**Basin—Continued.**

Veins, fine free gold.

Schrader, F. C., The Chalk Mountain, Quartz Mountain, Gold Basin and King mining districts, Nevada: U. S. Geol. Survey P. N. 17276, September 15, 1927.

U. S. G. S. Carson Sink topographic map.

Cross (Fallon, Terrell). Mn, Ag, Au, Cu, Pb.

12 miles NE. Schurz, S. P. R. R.

Tertiary volcanics.

Veins, replacements.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 5-6, 1923.

Schrader, F. C., Mining districts in the Carson Sink region, Nevada: Report in preparation.

Min. Res. 1923, pt. 1, p. 494.

1924, pt. 1, p. 431.

1925, pt. 1, p. 675.

1926, pt. 1, p. 530.

U. S. G. S. Carson Sink topographic map.

L. (Silver Hill). Ag, Au, Pb, Cu.

70 miles SE. Lovelock, S. P. R. R.

Granite and slate.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 6, 1923.

Schrader, F. C., Mining districts in the Carson Sink region, Nevada: Report in preparation.

U. S. G. S. Carson Sink topographic map.

mp. Au, Ag.

35 miles SW. Lovelock, 10 miles NW. White Plains (Huxley Station), S. P. R. R.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 182, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 6, 1923.

U. S. G. S. Carson Sink topographic map.

e. Pb, Ag, Sb.

E. Humboldt Lake on W. flank of Humboldt Lake Range; extends into Pershing County.

Jurassic shales.

Lodes.

Lincoln, F. C., op. cit.

U. S. G. S. Carson Sink topographic map.

e. Au, Ag, Pb.

In NW. Churchill County 15 miles NE. of Fernley, S. P. R. R.

Rhyolite, dacite and andesite.

Veins.

Lincoln, F. C., op. cit.

U. S. G. S. Wadsworth topographic map.

CHURCHILL COUNTY—Continued.

Mountain Wells (LaPlata). Ag.

30 miles E. Fallon, S. P. R. R.

Lincoln, Francis Church, Mining districts and mineral resources
p. 8, 1923.

U. S. G. S. Carson Sink topographic map.

Sand Springs. Au, Ag. (Salt.)

15 miles SE. Fallon, S. P. R. R.

Tertiary volcanics, Triassic and Jurassic sediments.

Veins.

Schrader, F. C., Mining districts in the Carson Sink region, Nevada
in preparation.

Min. Res. 1923, pt. 1, p. 494.

1928, pt. 1, p. 455.

U. S. G. S. Carson Sink topographic map.

Shady Run. Au, Ag, Pb.40 miles SE. Lovelock, S. P. R. R., and equal distance from Fallon
Quartzite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 9-10, 1923.

U. S. G. S. Carson Sink topographic map.

South Fairview. Au, Ag.

42 miles ESE. Fallon, S. P. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Mining districts in the Carson Sink region, Nevada
in preparation.

U. S. G. S. Carson Sink topographic map.

**Table Mountain (Boyer, Cottonwood Canyon, Bolivia). Ni, Co, Cr,
Ag, Sb.**

25-60 miles SE. Lovelock, S. P. R. R.

Triassic sediments cut by diorite capped by Tertiary volcanics.

Veins.

Schrader, F. W., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 194, 196 andLincoln, Francis Church, Mining districts and mineral resources
pp. 11-13, 1923.

U. S. G. S. Carson Sink topographic map (southern part of district).

Toy (Browns). W.

2 miles S. Toy section house (formerly Browns), S. P. R. R.

Sediments cut by granite.

Contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.Hess, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits
United States: U. S. Geol. Survey Bull. 725, pp. 287-289, 1918.Lincoln, Francis Church, Mining districts and mineral resources
p. 13, 1923.

Min. Res. 1925, pt. 1, p. 612.

U. S. G. S. Carson Sink topographic map.

Westgate. Ag, Pb, Au.

42-54 miles ESE. Fallon, S. P. R. R.

Jurassic limestone.

CHURCHILL COUNTY—Continued.

gate—Continued.

Veins, replacements.

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Cloud (Copperoid). Cu, Zn, Fe, Ag.

35 miles SE. Lovelock, S. P. R. R.

Triassic sediments cut by granite and diorite and capped by Tertiary volcanics.

Replacements, contact metamorphic.

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U. S. G. S. Carson Sink topographic map.

der (Hercules). Ag, Au, Cu, Zn.

57 miles by road SE. Fallon, S. P. R. R.

Tertiary volcanics and lake beds.

Veins.

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1926, pt. 1, p. 530.

U. S. G. S. Carson Sink topographic map.

CLARK COUNTY

ite (Railroad Pass, Vincent). Au.

22 miles by road SE. Las Vegas, U. P. R. R.; 12 miles E. Erie, U. P. R. R.

Igneous rocks.

Veins and stringers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

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U. S. G. S. St. Thomas and Camp Mohave topographic maps.

k Mountains. Fe, Mn.

Near Colorado River.

Mesozoic sediments overlain by Tertiary volcanics.

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U. S. G. S. St. Thomas and Camp Mohave topographic maps.

leston. Pb, Zn, Ag.

35 miles W. Las Vegas, U. P. R. R.

Min. Res. 1926, pt. 1, p. 530.

1928, pt. 1, p. 455.

1929, pt. 1, p. 652.

U. S. G. S. Las Vegas topographic map.

CLARK COUNTY—Continued.

- Copper King (Bunkerville, Great Eastern, Key West).** Cu, Au, Ag, N
15 miles S. Bunkerville and 15 miles NE. St. Thomas, U. P. R. R.
Pre-Cambrian gneiss intruded by basic dikes.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals of Nevada*.
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1929, pt. 1, p. 652.
U. S. G. S. St. Thomas topographic map.
- Crescent.** Au, Ag, Pb, Cu, Mo, V.
6 miles E. Nipton, U. P. R. R.
Pre-Cambrian metamorphic rocks cut by granite intrusions and
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals of Nevada*.
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U. S. G. S. Ivanpah topographic map.
- Dike.** Pb.
1 mile N. Dike, U. P. R. R.; 15 miles N. Las Vegas, U. P. R. R.
Paleozoic limestones.
Veins.
Min. Res. 1926, pt. 1, p. 530.
U. S. G. S. Las Vegas topographic map.
- Eldorado (Colorado, Nelson).** Au, Ag, Cu, Pb.
24 miles N. Searchlight, B. & S. R. E., in Opal Mountains.
Pre-Cambrian granite and gneiss cut by acidic intrusives and
Tertiary volcanics.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals of Nevada*.
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*.
pp. 19-20, 1923.
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1928, pt. 1, p. 455.
1929, pt. 1, p. 652.
U. S. G. S. Camp Mohave and Nelson (adv.) topographic maps.

CLARK COUNTY—Continued.

- Peak.** Ag, Au, Zn.
3 miles N. Las Vegas, U. P. R. R.
Paleozoic limestones.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 20-21, 1923.
U. S. G. S. Las Vegas topographic map.
- Butte.** Au, Ag, Cu, Zn.
3 miles SE. St. Thomas, U. P. R. R.
Pre-Cambrian complex cut by acidic and basic dikes.
Veins, replacements.
Schradner, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
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Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
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- Shah.** Ag.
W. Clark County and in California.
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Nevada: Report in preparation.
U. S. G. S. Ivanpah topographic map.
- Vegas.** Mn.
3 miles SE. Las Vegas, U. P. R. R.
Tertiary volcanics.
Replacements.
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U. S. G. S. St. Thomas topographic map.
- (St. Thomas, Muddy Mountains).** Cu, Ag.
3 miles SE. Moapa, S. P. L. A. & S. L. R. R.
Paleozoic and Mesozoic sediments capped by Tertiary volcanics.
Veins.
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Survey Bull. 208, 1903, pp. 136-138.
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through the Virgin Range to the Grand Wash Cliffs, Ariz.: U. S. Geol.
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U. S. G. S. St. Thomas topographic map.
- Whitlight.** Au, Ag, Cu, Pb.
Station B. & S. R. R.

CLARK COUNTY—Continued.

Searchlight—Continued.

Pre-Cambrian complex cut by quartz monzonite and capped by volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

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1925, pt. 1, p. 676.

1926, pt. 1, p. 531.

1928, pt. 1, p. 455.

U. S. G. S. Camp Mohave topographic map.

Sloan. Ra.

2 miles S. Sloan, U. P. R. R.

Tertiary rhyolite flow.

Coating on walls of joints.

Lincoln, Francis Church, Mining districts and mineral resources of Clark County, Nevada, p. 27, 1923.

U. S. G. S. Ivanpah topographic map.

Sunset (Lyons). Au.

15 miles SE. Jean, U. P. R. R.

Granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Clark County, Nevada, pp. 27-28, 1923.

Min. Res. 1928, pt. 1, p. 455.

U. S. G. S. Ivanpah and Goodsprings topographic maps.

Sutor. Ra.

2 miles W. Sutor, U. P. R. R.

Sandstones underlying Permian limestone.

Patches of carnotite with manganese oxide on fractures and joints.

Lincoln, Francis Church, Mining districts and mineral resources of Clark County, Nevada, p. 28, 1923.

U. S. G. S. Ivanpah topographic map.

Yellow Pine (Goodsprings, Potosi). Zn, Pb, Cu, Au, Ag, Pt, Pd, Co,

8 miles NW. Jean, U. P. R. R.

Paleozoic sediments cut by dikes.

Replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 190-191, 1917.

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- 1924, pt. 1, pp. 431-432, 470.
- 1925, pt. 1, pp. 676-677.
- 1926, pt. 1, pp. 531-532.
- 1927, pt. 1, p. 447.
- 1928, pt. 1, pp. 455-456.
- 1929, pt. 1, pp. 47, 652-653.
- S. G. S. Goodsprings, Ivanpah and Las Vegas topographic maps.

DOUGLAS COUNTY

- Min. Cu, Fe, Au, Pl.
- Adjoins Yerington district (Lyon County) on the W. and Mount Siegel district on the SW.
- Triassic sediments cut by granite.
- Contact metamorphic, veins and placer.
- Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 33, 1923.
- Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.
- Min. Res. 1924, pt. 1, p. 432.
- 1928, pt. 1, p. 456.
- 1929, pt. 1, p. 653.
- S. G. S. Wellington topographic map.
- Markleville (Eagle). Au, Cu, Ag.
- 10 miles SE. Minden, V. & T. R. R., on W. slope Pine Nut Range.
- Porphyry, Tertiary volcanics and lake beds.
- Veins.
- Shrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
- Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 33, 1923.
- Min. Res. 1923, pt. 1, p. 495.
- 1928, pt. 1, p. 456.
- S. G. S. Markleville topographic map.
- Markleville. Cu, Ag, Au, Pl.
- West W. town of Genoa, on E. slope Sierra Nevada.
- Triassic sediments intruded by Cretaceous granite.
- Veins, replacements, and placers.
- Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 34-35, 1923.
- S. G. S. Carson topographic map.

DOUGLAS COUNTY—Continued.

Mount Siegel. Au, Pl.

20 miles E. Minden, V. & T. R. R.

Placers.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 35, 1923.

Min. Res. 1923, pt. 1, p. 495.

1929, pt. 1, p. 653.

U. S. G. S. Markleeville topographic map.

Mountain House (Holbrook, Pine Nut). Au, Ag.

In Pine Nut Range on California border.

Hill, J. M., Some mining districts in northeastern California and western Nevada: U. S. Geol. Survey Bull. 594, p. 54, 1915.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 35, 1923.

Min. Res. 1917, pt. 1, p. 283.

1923, pt. 1, p. 495.

1924, pt. 1, p. 432.

1925, pt. 1, p. 677.

1926, pt. 1, p. 532.

U. S. G. S. Wellington and Markleeville topographic maps.

Red Canyon (Silver Lake). Au, Ag, Pb.

18 miles SE. Minden, V. & T. R. R., in S. part Pine Nut Range.

Triassic sediments cut by quartz monzonite.

Veins, contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 36, 1923.

Min. Res. 1923, pt. 1, p. 495.

1926, pt. 1, p. 532.

1929, pt. 1, p. 653.

U. S. G. S. Markleeville and Wellington topographic maps.

Silver Glimmer (Wellington). Au, Ag, Cu.

30 miles SSE. Minden, V. & T. R. R., in SE. part Pine Nut Range.

Quartz monzonite, probably Cretaceous.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 193, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 37, 1923.

Min. Res. 1923, pt. 1, p. 495.

1924, pt. 1, p. 432.

1926, pt. 1, p. 532.

U. S. G. S. Wellington topographic map.

ELKO COUNTY

Alder. Au.

8 miles N. Gold Creek.

Min. Res. 1916, pt. 1, p. 475.

Aura (Bull Run, Columbia). Au, Pl, Ag, Pb, Zn.

70 to 95 miles NNW. Elko, S. P. R. R., W. P. R. R., in Bull Run or tennial Range.

Paleozoic sediments cut by granodiorite.

Veins and placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, pp. 190, 192-194, 1917.

ELKO COUNTY—Continued.

Full Run, Centennial, Columbia)—Continued.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 37-38, 1923.

l. Res. 1929, pt. 1, p. 653.

Pb, Ag.

miles W. Good Hope, in Burner Hills.

osite.

ns.

coln, Francis Church, Mining districts and mineral resources of Nevada,
p. 38, 1923.

Au, Ag.

tion S. P. R. R., W. P. R. R.

ozoic sediments cut and capped by Tertiary volcanics.

ns, replacements.

trader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

l. Res. 1908, pt. 1, p. 476.

Ion (Copper Mountain, Cornwall). Au, Pl, Cu, Ag, Pb, Sb.

miles NNE. Elko, 50 miles NNW. Deeth, S. P. R. R., W. P. R. R.

ozoic sediments cut by granite.

tact metamorphic, replacements, placers.

trader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 39-40, 1923.

Kit Carson, Porter, Salmon River). Cu, Ag, Au.

tion, O. S. L.

ozoic sediments cut by granite.

tact metamorphic, veins, replacements.

trader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 193, 1917.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 40-41, 1923.

trader, F. C., Report in preparation.

l. Res. 1922, pt. 1, p. 320.

1923, pt. 1, p. 495.

1925, pt. 1, p. 677.

1926, pt. 1, p. 532.

1928, pt. 1, p. 456.

1929, pt. 1, pp. 653-654.

pia. Au, Ag.

miles NNW. Elko, S. P. R. R., W. P. R. R.

tiary volcanics.

ns.

trader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States, p. 194, 1917.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 41-42, 1923.

Mn.

miles E. Decoy, N. N. R. R., in Toano Range.

boniferous limestone.

placements.

dee, J. T., and Jones, E. L., Jr., Deposits of manganese ore in Nevada:
U. S. Geol. Survey Bull. 710-f, p. 241, 1920.

Delno). Au, Ag, Pb.

miles N. Montello, S. P. R. R.

ELKO COUNTY—Continued.

Delano (Delno)—Continued.

Panther mining property at Delno to mill and ship at increased

Lake Mining Review, vol. 26, No. 3, p. 17, May 15, 1924.

Min. Res. 1918, pt. 1, p. 233.

1919, pt. 1, p. 388.

1920, pt. 1, p. 321.

1921, pt. 1, p. 381.

1922, pt. 1, p. 320.

1923, pt. 1, p. 496.

1924, pt. 1, p. 432.

1925, pt. 1, p. 677.

1926, pt. 1, pp. 532-533.

1928, pt. 1, p. 456.

1929, pt. 1, p. 654.

Delker. Cu.

25 miles NE. Currie, N. N. R. R.

Limestones and quartzites; quartz monzonite.

Veins, contact metamorphic.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 42, 1923.

Divide. Ag, Au.

8 miles NW. Tuscarora at head of Dry Creek.

Min. Res. 1916, pt. 1, p. 474.

1918, pt. 1, p. 233.

Dolly Varden (Mizpah, Granite). Cu, Pb, Ag, Au.

20 miles E. Mizpah, N. N. R. R., 16 miles NE. Currie.

Carboniferous shale and limestone intruded by quartz monzonite.

Veins, contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, pp. 193, 200, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 42-43, 1923.

Min. Res. 1925, pt. 1, p. 678.

1926, pt. 1, p. 533.

1929, pt. 1, p. 654.

Edgemont (Centennial). Au, Ag, Pb.

92 miles NNW. Elko, S. P. R. R., W. P. R. R.

Paleozoic sediments.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 43, 1923.

Elk Mountain. Cu, Au, Sb.

90 miles SSE. Twin Falls, Idaho, O. S. L. R. R.

Paleozoic sediments cut by granite.

Contact metamorphic.

Schrader, F. C., A reconnaissance of the Jarbidge, Contact, and Elk
Mountain mining districts, Elko County, Nevada: U. S. Geol. Survey
Bull. 497, 1912.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 193, 1917.

Ferber. Cu, Pb, Au, Ag.

SE. corner Elko County, 40 miles S. Wendover, Utah, W. P. R. R.

Limestones cut by quartz monzonite.

Veins, contact metamorphic.

ELKO COUNTY—Continued.

Continued.

coln, Francis Church, Mining districts and mineral resources of Nevada, pp. 44-45, 1923.

láng, D. P., Ore deposits of the Deep Creek Range: Salt Lake Mining Review, March 30, 1924.

ber district in the Deep Creek country has potential possibilities for the future: Salt Lake Mining Review, vol. 26, No. 3, pp. 11-12, May 15, 1924.

. Res. 1925, pt. 1, p. 677.

a Spring (Allegheny). Cu, Pb.

side Toano Range.

ozoic limestones.

placements.

coln, Francis Church, Mining districts and mineral resources of Nevada, p. 45, 1923.

sin (Rowland). Cu, Au.

miles N. Elko, S. P. R. R., W. P. R. R.

. Res. 1926, pt. 1, p. 534.

1928, pt. 1, p. 457.

rcle (Midas, Summit). Au, Ag, Hg.

miles ENE. Golconda, S. P. R. R.

tiary volcanics.

us, replacements.

grader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 194, 1917.

coln, Francis Church, Mining districts and mineral resources of Nevada, pp. 45-46, 1923.

guson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

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. Res. 1922, pt. 1, p. 321.

1923, pt. 1, p. 496.

1924, pt. 1, p. 432.

1925, pt. 1, p. 678.

1926, pt. 1, p. 533.

1928, pt. 1, pp. 276, 457.

1929, pt. 1, p. 654.

ppe. Au, Ag.

miles NW. Elko, S. P. R. R., W. P. R. R.

tiary volcanics.

ns.

grader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 193, 194, 199, 1917.

coln, Francis Church, Mining districts and mineral resources of Nevada, pp. 46-47, 1923.

Mountain (Gold Creek). Au, Pl, Ag.

miles N. Elko, S. P. R. R., W. P. R. R.

ns and placers.

coln, Francis Church, Mining districts and mineral resources of Nevada, p. 47, 1923.

. Res. 1923, pt. 1, p. 496.

1924, pt. 1, p. 432.

1925, pt. 1, p. 678.

1926, pt. 1, p. 533.

1928, pt. 1, p. 457.

ELKO COUNTY—Continued

Ivanhoe. Hg.

60 miles NE. Golconda, S. P. R. R., W. P. R. R.

Rhyolite flow breccia.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
p. 47, 1923.

Min. Res. 1925, pt. 1, p. 46.

Jarvis. Au, Ag.

95 miles S. Twin Falls, Idaho, O. S. L. R. R.; 74 miles N. Elko
W. P. R. R.

Paleozoic sediments and Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.Lincoln, Francis Church, Mining districts and mineral resources
pp. 48-50, 1923.Par, John Furness, Mining methods of Jarvis district, Nevada
M. E. Trans. (preprint), No. 1400, 11 pp., January, 1925.Ferguson, H. G., The mining districts of Nevada: Econ. Geol.
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Min. Res. 1922, pt. 1, p. 321.

1923, pt. 1, p. 496.

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1925, pt. 1, p. 678.

1926, pt. 1, p. 533.

1928, pt. 1, p. 457.

1929, pt. 1, p. 654.

Kinsley. Ag, Cu, Pb.

8 miles SE. Currie, N. N. R. R.

Quartz monzonite porphyry intruding Cambrian limestones.

Contact metamorphic, veins.

Lincoln, Francis Church, Mining districts and mineral resources
p. 50, 1923.

Min. Res. 1914, pt. 1, p. 676.

Lafayette. Pb, Ag.

4 miles N. Tobar, W. P. R. R.

Min. Res. 1925, pt. 1, p. 678.

Lee. Cu.

30 miles SE. Elko, S. P. R. R., W. P. R. R.

Min. Res. 1917, pt. 1, p. 272.

1918, pt. 1, pp. 233-234.

1918, pt. 1, p. 389.

U. S. G. S. Halleck topographic (adv.) sheet.

Lime Mountain (Deep Creek). Cu, Au, Ag.

80 miles N. Elko, S. P. R. R., W. P. R. R.

Paleozoic limestone intruded by quartz porphyry, andesite and
Contact metamorphic.Lincoln, Francis Church, Mining districts and mineral resources
p. 51, 1923.

Min. Res. 1929, pt. 1, p. 654.

Loray (Luray, Leroy). Cu, Ag, Pb, Fe.

4½ miles SE. Loray siding, S. P. R. R.

Crystalline limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 50-51, 1923.

ELKO COUNTY—Continued.

Elko. Cu, Ag, Pb.

S. Tecoma, U. P. R. R., in Pilot Range.

Carboniferous sediments cut by igneous rocks.

Replacements.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, pp. 158-159, 1915.

Immac (Lone Mountain). Pb, Ag, Cu, Au.

28 miles by wagon road NW. Elko, S. P. R. R., W. P. R. R.

Carboniferous limestone intruded by quartz monzonite and quartz monzonite porphyry.

Contact metamorphic.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 51, 1923.

Min. Res. 1922, pt. 1, p. 321.

1923, pt. 1, p. 496.

1924, pt. 1, p. 433.

1925, pt. 1, p. 678.

1926, pt. 1, p. 533.

1928, pt. 1, p. 457.

1929, pt. 1, p. 655.

Mountain City (Cope, Van Duzer). Cu, Au, Ag, Pb, Zn.

90 miles N. Elko, S. P. R. R., W. P. R. R., in NE. part Bull Run Range.

Paleozoic sediments cut by granodiorite and capped by Tertiary volcanics.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geological Survey Bull. 624, pp. 191-192, 194, 197-198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 52, 58-59, 1923.

Min. Res. 1921, pt. 1, p. 582.

1925, pt. 1, p. 677.

1926, pt. 1, p. 532.

Springs (Medicine Springs). Pb, Zn, Ag, barite.

40 miles WSW. Currie, N. N. R. R., N. end Ruby Hills.

Permian limestones, shales, and quartzites.

Replacements.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 52-53, 1923.

Min. Res. 1923, pt. 1, p. 496.

1924, pt. 1, p. 433.

1925, pt. 1, pp. 678-679.

1926, pt. 1, p. 534.

1928, pt. 1, p. 457.

1929, pt. 1, p. 655.

U. S. G. S. Halleck topographic (adv.) sheet.

tor. Ag.

Station on W. P. R. R.

Min. Res. 1917, pt. 1, p. 272.

road (Bullion). Ag, Au, Cu, Pb, Zn.

27 miles SSW. Elko, 12 miles SE. Palisade, S. P. R. R., W. P. R. R.

Ordovician limestone cut by granodiorite and quartz porphyry.

Replacements, contact metamorphic, veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192-193, 195, 196, 198, 1917.

ELKO COUNTY—Continued.**Railroad (Bullion)—Continued.**

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 53-54, 1923.

Min. Res. 1923, pt. 1, p. 496.
1924, pt. 1, p. 433.
1925, pt. 1, p. 679.
1926, pt. 1, p. 534.
1928, pt. 1, p. 457.
1929, pt. 1, p. 655.

U. S. G. S. Halleck topographic (adv.) sheet.

Rock Creek (Falcon). Ag.

70 miles from Tuscarora, in Independence Range.

Tertiary andesite.

Veins.

Min. Res. 1922, pt. 1, p. 321.
1928, pt. 1, p. 457.
1929, pt. 1, p. 655.

Ruby Range (Ruby Mountain Range, Valley View). Pb, Zn, Ag, Au, (Not mining district.)

15 miles W. Tobar, W. P. R. R.

Granitic rocks, Paleozoic sediments.

Replacements, contact metamorphic.

Hill, J. M. Notes on some mining districts in eastern Nevada: U. S. Geol. Survey Bull. 648, pp. 54-63, 1916.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 191, 1917.

Hess, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 245-309, 1917.

Min. Res. 1914, pt. 1, pp. 676-677.
1915, pt. 1, p. 630.
1917, pt. 1, p. 273.
1923, pt. 1, p. 497.
1924, pt. 1, p. 433.
1925, pt. 1, p. 679.
1926, pt. 1, p. 534.
1928, pt. 1, p. 457.
1929, pt. 1, p. 655.

U. S. G. S. Halleck topographic (adv.) sheet.

Ruby Valley (Smith Creek). Pb, Ag, Zn.

45 miles W. Currie, N. N. R. R.; 35 miles S. Halleck, S. P. R. R.

Paleozoic limestones intruded by biotite-granite.

Lenses.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 193, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 54-55, 1923.

U. S. G. S. Halleck topographic (adv.) sheet.

Spruce Mountain. Pb, Cu, Ag, Au, Mn.

58 miles S. Wells, S. P. R. R.; 15 miles NW. Mizpah, N. N. R. R.; 15 miles S. Jasper, W. P. R. R.

Paleozoic sediments cut by rhyolite.

Replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

ELKO COUNTY—Continued.**Ice Mountain**—Continued.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 55-57, 1923.

Schrader, F. C., Spruce Mountain district, Elko County, Nevada: Nevada State Bureau of Mines and Mackey School of Mines Bulletin, August, 1931.

Min. Res. 1922, pt. 1, p. 321.

1923, pt. 1, p. 497.

1924, pt. 1, p. 433.

1925, pt. 1, p. 679.

1926, pt. 1, p. 534.

1928, pt. 1, p. 458.

1929, pt. 1, p. 655.

Tecoma. Pb, Ag, Cu, Au.

10 miles NNE. Tecoma, S. P. R. R.

Limestone, overlain and underlain by quartzite.

Replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 57, 1923.

Min. Res. 1922, pt. 1, p. 321.

1923, pt. 1, p. 497.

1924, pt. 1, p. 433.

1925, pt. 1, p. 679.

1926, pt. 1, p. 534.

1928, pt. 1, p. 458.

1929, pt. 1, p. 655.

Hot Range (Gosiute Range). Cu, Pb, Fe. (Not a mining district.)

E. Cobre.

Quartzites and limestones, the latter prevailing; also igneous rocks.

Veins.

Hill, J. M., Notes on some mining districts in eastern Nevada: U. S. Geol. Survey Bull. 648, pp. 95-102, 1916.

Min. Res. 1914, pt. 1, p. 677.

Carora. Au, Pl, Ag.

50 miles NW. Elko, S. P. R. R., W. P. R. R.

Tertiary volcanics.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 190, 191, 193, 194, 197, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 57-58, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 321.

1925, pt. 1, pp. 679-680.

1926, pt. 1, p. 534.

1928, pt. 1, p. 458.

Warm Creek. Zn, Pb.

SE. side Warm Creek Ridge, E. Clover Valley, 25 miles SE. Halleck, S. P. R. R.

Fossiliferous limestone and shale of probable Permian age.

Replacements.

ELKO COUNTY—Continued.**Warm Creek—Continued.**

Lincoln, Francis Church, Mining districts and mineral resources of N
p. 59, 1923.

Min. Res. 1925, pt. 1, p. 680.

1926, pt. 1, p. 534.

1928, pt. 1, p. 458.

White Horse. Cu, Pb.

SW. flank Mount Pisgah, 45 miles E. Currie, N. N. R. R.

Quartz monzonite stock.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of N
p. 59, 1923.

ESMERALDA COUNTY**Alpine. Au.**

Near Lone Mountain.

Paleozoic limestone and slate cut by granite.

Veins, replacements.

Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nevada:

Geol. Survey Prof. Paper 55, pp. 81-83, 1906.

Min. Res. 1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

Argentite. Ag.

40 miles S. Blair Junction, T. & G. R. R., 24 miles W. Silver Peak.

Rhyolite and limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of N
p. 60, 1923.

U. S. G. S. Silver Peak topographic map.

Rock. Au, Ag, Hg.

4 miles N. Blair Junction; 35 miles W. Tonopah, T. & G. R. R.

Min. Res. 1928, pt. 1, pp. 276, 458.

1929, pt. 1, p. 655.

U. S. G. S. Tonopah topographic map.

Saddle. Pb, Ag.

Station, T. & G. R. R., in Monte Cristo Range.

Tertiary volcanics.

Veins.

Min. Res. 1926, pt. 1, p. 535.

U. S. G. S. Tonopah topographic map.

Crow Springs. Ag, Pb, Cu, Au.

11 miles NW. Millers, T. & G. R. R., in Monte Cristo Range.

Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of N
pp. 62-63, 1923.

U. S. G. S. Tonopah topographic map.

Cuprite. Au, Ag, Cu, Pb, Hg.

14 miles S. Goldfield, T. & G. R. R.

Cambrian sediments cut by dikes of diorite and Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 196

1917.

ESMERALDA COUNTY—Continued.

te—Continued.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 63-64, 1923.

U. S. G. S. Lida topographic map.

le (Gold Mountain). Ag, Au, Pb.

5 miles S. Tonopah, T. & G. R. R.

Tertiary volcanics.

Feins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 64-66, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, pp. 322-323.

1923, pt. 1, p. 498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

1928, pt. 1, pp. 458-459.

1929, pt. 1, p. 656.

U. S. G. S. Tonopah and Lida topographic maps.

. Ag.

2 miles SW. Tonopah, T. & G. R. R.

Tertiary volcanics.

Feins.

Min. Res. 1923, pt. 1, p. 497.

U. S. G. S. Tonopah topographic map.

Au, Ag, Pb.

8 miles S. Coaldale, T. & G. R. R.

Paleozoic sediments cut by granite.

Feins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 66, 1923.

Min. Res. 1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

U. S. G. S. Silver Peak and White Mountain topographic maps.

r (Windypah). Au, Pl, Ag.

5 miles SW. Blair Junction, T. & G. R. R.

Paleozoic sediments cut by granite.

Feins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 66, 1923.

U. S. G. S. Silver Peak topographic map.

rt (Desert). Au, Ag, Cu, Pb.

5 miles W. Tonopah, T. & G. R. R.

Paleozoic sediments and Tertiary volcanics.

Feins.

Opening up of a brand new mining camp in Nevada is promised by developments of a substantial kind: Salt Lake Mining Review, vol. 26, No. 20, January 30, 1925, pp. 9-11.

ESMERALDA COUNTY—Continued.

Gilbert (Desert)—Continued.

Ferguson, H. G., The Gilbert district, Nevada: U. S. Geol. Survey pp. 125-145, 1928; The mining districts of Nevada: Econ. vol. 24, No. 2, March-April, 1929.

Revival seen at Gilbert, Nevada: Eng. and Min. Jour., vol. 132, No. 2, July 27, 1931.

Min. Res. 1917, pt. 1, p. 274.

1918, pt. 1, p. 235.

1920, pt. 1, p. 322.

1921, pt. 1, p. 382.

1922, pt. 1, p. 322.

1923, pt. 1, p. 497.

1924, pt. 1, p. 433.

1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

1928, pt. 1, p. 458.

1929, pt. 1, p. 655.

U. S. G. S. Tonopah topographic map.

Goldfield. Au, Ag, Cu, Pb, Mn, Zn.

Station, T. & G. R. R.

Tertiary volcanics underlain by Cambrian sediments cut by granite veins, replacements.

Jennings, E. P., The Goldfield district, Nevada: Can. Min. Intelligencer, pp. 39-45, 1905.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 190-191, 1915; 195, 196, 197, 198, 199, 200, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 67-73, 1923.

Barbour, Percy E., The rise and decadence of Goldfield: Min. Jour., August, 1923, pp. 399-405.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Interest in gold prompts activity at Goldfield: E. and M. Jour., vol. 132, No. 6, p. 272, September 28, 1931.

Min. Res. 1922, pt. 1, p. 322.

1923, pt. 1, pp. 497-498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

1928, pt. 1, p. 459.

1929, pt. 1, p. 656.

U. S. G. S. Lida and Goldfield special topographic maps.

Good Hope. Ag.

7 miles S. Piper Peak, W. flank Silver Peak Range.

Slates, probably Ordovician, with interbedded quartzites.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 73, 1923.

U. S. G. S. Lida and Silver Peak topographic maps.

Hornsilver (Lime Point). Au, Ag, Pb, Zn, Cu.

25 miles S. Goldfield, T. & G. R. R.

Cambrian limestone and shales cut by granite.

Veins.

ESMERALDA COUNTY—Continued.

silver (Lime Point)—Continued.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194 and 196, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 73-75, 1923.

Min. Res. 1922, pt. 1, p. 323.

1923, pt. 1, p. 498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 680.

1926, pt. 1, p. 535.

1928, pt. 1, p. 459.

U. S. G. S. Lida topographic map.

dyke (Southern Klondyke). Au, Pl, Ag, Pb, Cu.

4 miles S. Tonopah, T. & G. R. R.

Cambrian sediments cut by granite and overlain by Tertiary volcanics.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 199, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 75-76, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geol., vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 323.

1923, pt. 1, p. 498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 681.

1926, pt. 1, p. 535.

1928, pt. 1, p. 459.

1929, pt. 1, p. 656.

U. S. G. S. Lida topographic map.

(Alida Valley, Tule Canyon). Au, Pl, Ag, Pb, Cu.

10 miles SW. Goldfield, T. & G. R. R.

Cambrian sediments cut by quartz monzonite and capped by Tertiary volcanics.

Veins and impregnations, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 76-77, 1923.

Min. Res. 1922, pt. 1, p. 323.

1923, pt. 1, p. 498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 681.

1926, pt. 1, p. 536.

U. S. G. S. Lida topographic map.

Mountain (West Divide). Ag, Au, Pb, Zn, Cu.

4 miles NNW. Goldfield, T. & G. R. R.

Cambrian sediments cut by granite and diorite, capped by Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 198, 1917.

ESMERALDA COUNTY—Continued.

Lone Mountain (West Divide)—Continued.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 77-78, 1923.

Min. Res. 1922, pt. 1, p. 323.

1924, pt. 1, p. 434.

1925, pt. 1, p. 681.

1926, pt. 1, p. 536.

1928, pt. 1, pp. 459-460.

1929, pt. 1, p. 656.

U. S. G. S. Lida and Tonopah topographic maps.

Montezuma. Au, Ag, Pb, Cu.

7 miles W. Goldfield, T. & G. R. R.

Cambrian sediments cut by granite and diorite and capped by
volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 196, 198

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 78-79, 1923.

Min. Res. 1923, pt. 1, p. 498.

1924, pt. 1, p. 434.

1925, pt. 1, p. 681.

1926, pt. 1, p. 536.

1928, pt. 1, p. 460.

1929, pt. 1, pp. 656-657.

U. S. G. S. Lida topographic map.

Palmetto. Au, Pl, Ag, Pb.

42 miles SW. Goldfield, T. & G. R. R.

Paleozoic sediments cut by granite.

Veins, contact metamorphic, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 79-80, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology,
No. 2, March-April, 1929.

Min. Res. 1913, pt. 1, p. 823.

1916, pt. 1, p. 479.

1917, pt. 1, p. 276.

1924, pt. 1, p. 434.

1928, pt. 1, p. 460.

1929, pt. 1, p. 657.

U. S. G. S. Silver Peak and Lida topographic maps.

Railroad Springs. Au, Ag, Cu.

25 miles SW. Goldfield, T. & G. R. R., T. & T. R. R.

Cambrian limestones and shales intruded by diorite dikes and ca
places by Tertiary rhyolite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 80-81, 1923.

U. S. G. S. Lida and Silver Peak topographic maps.

Silver Peak (Mineral Ridge, Red Mountain). Au, Ag, Pb.

20 miles S. Blair Station, T. & G. R. R.

Paleozoic sediments cut by granite and diorite, capped by Tert
canics.

ESMERALDA COUNTY—Continued.**Silver Peak (Mineral Ridge, Red Mountain)**—Continued.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 81-82, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 323.

1923, pt. 1, p. 498.

1924, pt. 1, p. 435.

1925, pt. 1, p. 681.

1926, pt. 1, p. 536.

1928, pt. 1, p. 460.

1929, pt. 1, p. 657.

U. S. G. S. Silver Peak topographic map.

Sylvania (Green Mountain). Ag, Pb.

2 miles SE. Oasis, Calif., near California-Nevada border, in Sylvania Mountains.

Limestones and quartzites intruded by granite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 83, 1923.

Min. Res. 1928, pt. 1, p. 460.

1929, pt. 1, p. 657.

U. S. G. S. Lida topographic map.

Old Gold Mountain, Bonnie Clare, Oriental Wash. Au, Pl, Ag, Cu, Pb.

5 miles W. Bonnie Clare, T. & T. R. R.

Cambrian sediments cut by granite and capped by Tertiary volcanics.

Veins and placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 83-84, 1923.

Min. Res. 1923, pt. 1, p. 498.

1924, pt. 1, p. 435.

1925, pt. 1, p. 681.

1926, pt. 1, p. 536.

U. S. G. S. Lida topographic map.

White Mountains (Fish Lake Valley). Hg.

2 miles SW. Tonopah, T. & G. R. R.

Rotary furnace at B. & B. quicksilver mine producing mercury each month: Nev. Mining Press, vol. 11, No. 443, November 23, 1928, p. 1.

Schuetz, C. N., Occurrence of quicksilver ore bodies: A. I. M. M. E. Tech. Pub. 335, pp. 43-44, July, 1931. (B. & B. quicksilver mine.)

Min. Res. 1928, pt. 1, p. 274.

U. S. G. S. White Mountain topographic map.

White Mountain. Au, Ag.

Near Lone Mountain.

Paleozoic limestones and slates cut by granite and alaskite.

Veins.

Purp, J. E., Ore deposits of the Silver Peak quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 55, pp. 80-81, 1906.

EUREKA COUNTY

Alpha. Ag, Pb.

5 miles E. Alpha, E. & P. R. R.

Devonian limestone.

Sheeted zones, replacements.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 85, 1923.

U. S. G. S. Roberts Mountains topographic map.

Antelope. Pb, Ag, Cu.

SW. corner of county.

Min. Res. 1916, pt. 1, p. 479.

1917, pt. 1, p. 277.

U. S. G. S. Roberts Mountains topographic map.

Beowawe. Hg.

Station, S. P. R. R., W. P. R. R.

Cinnabar mining at Beowawe: Nevada Mining Press, October 2,

Buckhorn (Mill Canyon). Au, Ag, Pb.

35 miles SSW. Palisade, S. P. R. R., W. P. R. R.; 30 miles S. Beowawe, R. R.

Ordovician limestone intruded by granodiorite and capped by eruptives.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 85-86, 1923.

Schrader, F. C.: Report in preparation.

Cortez (Bullion Hill, Mount Tenabo). Ag, Pb, Au, Cu, Zn.

36 miles S. Beowawe, S. P. R. R., W. P. R. R.

Paleozoic sediments cut by granite and porphyries and capped by volcanics.

Replacements, veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the

United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 86-87, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 324.

1926, pt. 1, p. 536.

1928, pt. 1, p. 460.

1929, pt. 1, pp. 657-658.

Diamond. Ag, Pb.

25 miles N. Eureka, E. & P. R. R.

Limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 87, 1923.

U. S. G. S. Roberts Mountains topographic map.

Eureka (Pinto, Prospect, Ruby Hill, Secret Canyon, Silverado, Spring).

Ag, Pb, Au, Cu, Zn, Fe, As.

Station E. & P. R. R., 84 miles S. Palisade, S. P. R. R.

Paleozoic sediments, granite porphyry, rhyolite and basalt.

Replacements, veins.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the Overland Route: U. S. Geol. Survey Bull. 612, pp. 157, 168, 1915.

EUREKA COUNTY—Continued.

Eureka (Pinto, Prospect, Ruby Hill, Secret Canyon, Silverado, Spring Valley)—
Continued.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 190-192, 194-198, 200, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 88-93, 1923.

Bains, Thos. H., Location of future ores of the southwest: Mining Jour., Phoenix, Ariz., vol. 11, No. 9, pp. 5-7, September 30, 1927.

Nolan, Thos. B., A late Paleozoic positive area in Nevada: Am. Jour. Sci., 5th ser., vol. 16, pp. 153-161, August, 1928.

Ferguson, H. G., The mining districts of Nevada: Econ. Geol., vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, pp. 62, 324.

1923, pt. 1, p. 499.

1924, pt. 1, pp. 40, 435.

1925, pt. 1, pp. 681-682.

1926, pt. 1, pp. 536-537.

1928, pt. 1, pp. 460-461.

1929, pt. 1, pp. 658-659.

J. S. G. S. Roberts Mountains topographic map (westerly portion).

J. S. G. S. Eureka mining district topographic map.

Au, Pl.

10 miles NW. Carlin, S. P. R. R., W. P. R. R.

Tertiary volcanics cut by porphyritic intrusions.

Veins and placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 94, 1923.

Min. Res. 1923, pt. 1, p. 499.

1924, pt. 1, p. 435.

1925, pt. 1, p. 682.

1926, pt. 1, p. 537.

1929, pt. 1, p. 659.

Creek (Schroeder). Pb, Ag, Au, Sb, Cu.

15 miles NNW. Carlin, S. P. R. R., W. P. R. R.

Paleozoic sediments and Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 94-95, 1923.

Central Hill. Ag, Pb, Au, Cu, Zn.

1 miles SE. Mineral, E. & P. R. R.

Paleozoic sediments cut by porphyry.

Replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 197-199, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 95, 1923.

Min. Res. 1922, pt. 1, p. 324.

1923, pt. 1, p. 499.

1926, pt. 1, p. 537.

EUREKA COUNTY—Continued.**Mt. Hope.** Zn, Pb, Ag.

2 miles W. Mt. Hope Station, E. & P. R. R.

U. S. G. S. Roberts Mountains topographic sheet.

Mount Tenabo. (See Cortez).**Roberts.** Ag, Pb, Cu.

42 miles SE. Austin, N. C. R. R.

Syenite and limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 96, 1923.

U. S. G. S. Roberts Mountains topographic map.

Safford (Barth, Palisade). Ag, Au, Fe, Pb, Cu.

6 miles W. Palisade, S. P. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 192, 194, 195,
1917.Lincoln, Francis Church, Mining districts and mineral resources of
pp. 96-97, 1923.

Min. Res. 1924, pt. 1, p. 435.

1929, pt. 1, p. 659.

HUMBOLDT COUNTY**Amos (Awakening, Slumbering Hills).** Au, Pl, Ag.

30 miles NW. Winnemucca, S. P. R. R., W. P. R. R.

Veins, placers.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 97, 1923.

Min. Res. 1924, pt. 1, p. 436.

1925, pt. 1, p. 682.

1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Disaster and Paradise topographic maps.

Black Rock. Au, Ag.

Near Sulphur, W. P. R. R.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 192, 1917.

Min. Res. 1921, pt. 1, p. 364.

1922, pt. 1, p. 324.

1923, pt. 1, p. 499.

1924, pt. 1, p. 436.

1925, pt. 1, p. 682.

1926, pt. 1, p. 537.

1928, pt. 1, p. 461.

U. S. G. S. Disaster topographic map.

Disaster. Au, Pl.

100 miles NNW, Winnemucca, S. P. R. R., W. P. R. R.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.Lincoln, Francis Church, Mining districts and mineral resources of
p. 97, 1923.

U. S. G. S. Disaster topographic map.

HUMBOLDT COUNTY—Continued.

Golconda. Mn, Cu, Au, Pb, Zn, W, Fe.

3 miles ESE. Golconda, S. P. R. R.

Tertiary sediments and volcanics.

Bedded lenses.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 195, 197, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 97-98, 1923.

Min. Res. 1914, pt. 1, p. 684.

1916, pt. 1, p. 481.

1920, pt. 1, p. 324.

U. S. G. S. Sonoma Range topographic (adv.) map.

Ad Run (Adelaide). Cu, Ag, Au, Pl, Pb, Zn.

15 miles S. Golconda, S. P. R. R.

Triassic sediments cut by granite.

Veins, replacements, contact metamorphic, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 195, 200, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 99-100, 1923.

Min. Res. 1922, pt. 1, p. 324.

1923, pt. 1, p. 499.

1924, pt. 1, p. 436.

1925, pt. 1, p. 682.

1926, pt. 1, p. 537.

1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Sonoma Range topographic (adv.) map.

Grandpap. Au, Ag.

26 miles S. Winnemucca, S. P. R. R., W. P. R. R., in Grandpap Canyon.

Min. Res. 1911, pt. 1, p. 678.

U. S. G. S. Sonoma Range topographic (adv.) map.

Iron Point. Mn, Ag, Au, Pb.

S. Iron Point, S. P. R. R.

Shale and quartzite.

Lenses.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 98, 1923.

Min. Res. 1922, pt. 1, p. 324.

1923, pt. 1, p. 499.

1924, pt. 1, p. 436.

1925, pt. 1, p. 682.

1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Sonoma Range topographic (adv.) map.

Hickson Creek. Cu, Pb, Ag.

75 miles NNW. Humboldt, S. P. R. R.; 35 miles N. Sulphur, W. P. R. R.

Granite and limestone.

Veins, contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 193, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 98-99, 1923.

U. S. G. S. Disaster topographic map.

HUMBOLDT COUNTY—Continued.

National. Au, Ag, Sb.

74 miles N. Winnemucca, S. P. R. R., W. P. R. R., W. slope San
Range.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 1917.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the
United States, Part B, The Overland Route: U. S. Geol. Survey
612, p. 174, 1915.

Spurr, J. E., Tertiary gold quartz vein dike at National, Nevada:
Jour. Press, vol. 116, No. 25, Dec. 22, 1923, p. 1078.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 100-101, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology,
No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 324.

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1924, pt. 1, p. 436.

1925, pt. 1, p. 682.

1926, pt. 1, pp. 537-538.

1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Paradise topographic map.

New Central. Au, Ag, Pb.

25 miles W. Winnemucca.

Min. Res. 1922, pt. 1, p. 324.

1924, pt. 1, p. 436.

U. S. G. S. Lovelock topographic (adv.) map.

Paradise Valley (Mount Rose, Spring City). Au, Pl, Ag.

44 miles NNE. Winnemucca, S. P. R. R., W. P. R. R.; 12 miles N. G.
S. P. R. R.

Mesozoic metamorphosed slates.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 101, 1923.

Min. Res. 1922, pt. 1, p. 324.

1926, pt. 1, p. 538.

U. S. G. S. Paradise topographic map.

Preble (Potosi). Ag, Au.

5 miles E. Golconda, S. P. R. R.

Veins.

Min. Res. 1926, pt. 1, p. 538.

1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Sonoma Range topographic (adv.) map.

Rebel Creek (New Goldfields, Willow Creek). Au, Pl, Ag.

54 miles N. Winnemucca, S. P. R. R., W. P. R. R.

Metamorphosed slates and granites.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 101-102, 1923.

HUMBOLDT COUNTY—Continued.**el Creek (New Goldfields, Willow Creek)**—Continued.

Min. Res. 1922, pt. 1, p. 324.

U. S. G. S. Paradise topographic map.

Butte. Cu, Sb, Hg.

45 miles NW. Humboldt, S. P. R. R.; 15 miles N. Sulphur, W. P. R. R.

Gabbro cut by dikes of aplite.

Veins, disseminations.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 193, 195, 196, 199, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 102, 1923.

Min. Res. 1919, pt. 1, p. 396.

1923, pt. 1, p. 500.

1925, pt. 1, p. 682.

U. S. G. S. Disaster topographic map.

erman. Au.

23 miles N. Winnemucca, S. P. R. R., in Bloody Run Range.

Veins.

Min. Res. 1928, pt. 1, p. 461.

1929, pt. 1, p. 659.

U. S. G. S. Paradise topographic map.

n. Ag, Au.

28 miles N. Winnemucca, S. P. R. R.

Granite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 102, 1923.

U. S. G. S. Paradise topographic map.

oma Mountain (Harmony). Cu, Ag, Au, Zn.

5 miles SE. Winnemucca, S. P. R. R., W. P. R. R.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 195, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 102-103, 1923.

U. S. G. S. Sonoma Range topographic (adv.) map.

hur (Rabbit Hole). Ag, Hg (Sulphur).

2 miles SE. Sulphur, W. P. R. R.

Tertiary rhyolite and water-laid tuffs.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 103-104, 1923.

U. S. G. S. Lovelock topographic (adv.) map.

Mile. Au, Ag.

10 miles NW. Winnemucca, S. P. R. R., W. P. R. R.

Min. Res. 1925, pt. 1, p. 682.

1926, pt. 1, p. 538.

1928, pt. 1, p. 461.

U. S. G. S. Paradise topographic map.

yville (Columbia). Au, Pl.

120 miles NW. Winnemucca, S. P. R. R., W. P. R. R.

Veins, placers.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 104, 1923.

U. S. G. S. Disaster topographic map.

HUMBOLDT COUNTY—Continued.**Warm Springs (Vicksburg, Ashdown, Pueblo).** Au, Ag, Cu, Pb.

120 miles NW. Winnemucca, S. P. R. R., W. P. R. R.

Mica and clay slates intruded by core of porphyry and basalt and fls
W. by basalt.

Ore in quartz gangue.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful mineral

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 105, 1923.

Min. Res. 1926, pt. 1, p. 538.

U. S. G. S. Disaster topographic map.

Willow Point. Cu, Ag.

20 miles NNE. Winnemucca, S. P. R. R., W. P. R. R.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 105, 1923.

U. S. G. S. Paradise topographic map.

Winnemucca (Barrett Springs). Au, Pl, Ag, Pb, Cu.

5 miles WNW. Winnemucca, S. P. R. R., W. P. R. R.

Mesozoic metamorphosed slates, diorite.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful mineral

United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 199, 1

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 105-106, 1923.Increasing gold prospecting embraces entire world; many stri
reported: E. & M. Jour., vol. 132, No. 4, August 24, 1931, p. 18

Min. Res. 1922, pt. 1, p. 325.

1924, pt. 1, p. 436.

1926, pt. 1, p. 538.

U. S. G. S. Paradise topographic map.

LANDER COUNTY**Battle Mountain (Bannock, Copper Basin, Copper Canyon, Cottonwood****Rocky Canyon, Galena).** Au, Pl, Ag, Cu, Sb, Pb, Zn, As.

10 miles W. Battle Mountain, S. P. R. R., W. P. R. R.

Paleozoic sediments and Tertiary volcanics.

Veins, replacements, contact metamorphic, placers.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the

United States, Part B, The Overland Route: U. S. Geol. Surv

612, pp. 170-171, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful mineral

United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 199,

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 106-109, 1923.Ferguson, H. G., The mining districts of Nevada: Econ. Geology,
No. 2, March-April, 1929.Schrader, F. C., Notes on mining districts in eastern Nevada: R
preparation.

Min. Res. 1922, pt. 1, pp. 62, 325.

1923, pt. 1, p. 500.

1924, pt. 1, pp. 39, 436-437.

1925, pt. 1, pp. 682-683.

1926, pt. 1, pp. 538-539.

1928, pt. 1, p. 462.

1929, pt. 1, pp. 659-660.

U. S. G. S. Sonoma Range topographic (adv.) map.

LANDER COUNTY—Continued.

- Creek. Sb.**
10 miles S. Austin, N. C. R. R., W. slope Toiyabe Range.
Shales and slates with thin beds of quartzite and limestone.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 109, 1923.
- h Creek (Big Smoky, Smoky Valley). Au, Ag, Pb, Cu, Mo.**
12 miles S. Austin, N. C. R. R., E. flank Toiyabe Range.
Sedimentary rocks intruded by granodiorite.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 109-110, 1923.
U. S. G. S. Roberts Mountains topographic map.
- alo Valley. Au.**
17 miles S. Valmy, S. P. R. R.
Limestone and aplite.
Veins, replacements in limestone.
Schrader, F. C.: Report in preparation.
U. S. G. S. Sonoma Range topographic (adv.) map.
- ion (Campbell, Lander, Tenabo). Ag, Au, Pl, Pb, Cu, As.**
25 miles SW. Beowawe, S. P. R. R., E. slope Shoshone Range.
Paleozoic sediments capped by Tertiary volcanics.
Veins and placers.
Martin, A. H., The Lander mining district, Nevada: M. Science, vol. 61, pp.
508-511, 1910.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 197, 198,
1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 110-111.
- Min. Res. 1922, pt. 1, p. 325.**
1923, pt. 1, p. 500.
1924, pt. 1, p. 437.
1925, pt. 1, p. 683.
1926, pt. 1, p. 539.
1928, pt. 1, pp. 462-463.
1929, pt. 1, p. 660.
- i Basin. Au, Ag, traces of Cu and Pb.**
At Carroll, on Churchill County border.
Min. Res. 1928, pt. 1, p. 463.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 111, 1923.
- top (Kimberly, Mayesville). Cu, Pb, Au, Ag.**
18 miles SE. Battle Mountain, S. P. R. R., W. P. R. R.
Paleozoic sediments cut by diorite and andesite.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, pp. 193, 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 111-112, 1923.
Min. Res. 1922, pt. 1, p. 326.
1923, pt. 1, p. 500.
1924, pt. 1, p. 437.
1925, pt. 1, p. 683.
1926, pt. 1, p. 540.
1928, pt. 1, p. 463.

LANDER COUNTY—Continued.**Horse Canyon. Au.**

Near McCoy, 30 miles SSW. Battle Mountain, S. P. R. R., W. P. R. R.

Diorite and limestone.

Veins.

Schrader, F. C.: Report in preparation.

U. S. G. S. Sonoma Range topographic (adv.) map.

Jackson (Gold Park). Au.

44 miles S. of Austin, N. C. R. R. (See, also, Nye County.)

Min. Res. 1910, pt. 1, p. 520.

1911, pt. 1, p. 682.

1912, pt. 1, p. 800.

1913, pt. 1, p. 829.

1921, pt. 1, p. 385.

1925, pt. 1, p. 684.

Kingston (Bunker Hill, Santa Fe, Summit, Victorine). Au, Ag.

24 miles S. Austin, N. C. R. R., W. flank of Toiyabe Range.

Limestone interbedded with shales and slate.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 112-113, 1923.

Lewis (Dean, Mud Springs, Pittsburg). Ag, Au.

14 miles SE. Battle Mountain, S. P. R. R., W. P. R. R.

Paleozoic sediments cut by granite and andesite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 113-114, 1923.

Betty O'Neal mine: E. & M. Jour.-Press, March 15, 1924, pp. 449-452.

Min. Res. 1922, pt. 1, p. 326.

1923, pt. 1, pp. 500-501.

1924, pt. 1, p. 437.

1925, pt. 1, p. 684.

1926, pt. 1, p. 540.

1928, pt. 1, p. 463.

1929, pt. 1, p. 660.

McCoy. Au.

30 miles SSW. of Battle Mountain; access by automobile; 8 miles W. N. C. R. R.

Diorite and limestone.

Veins.

Schrader, F. C.: Report in preparation.

Min. Res. 1924, pt. 1, p. 437.

1929, pt. 1, p. 660.

U. S. G. S. Sonoma Range topographic (adv.) map.

New Pass. Au.

27 miles W. Austin, N. C. R. R., on border of Churchill County.

Limestone, porphyry and gabbro.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 114, 1923.

Ravenswood (Shoshone). Ag, Au, Cu, Pb.

20 miles NNW. Austin, N. C. R. R., 7 miles W. Silver Creek side N. C. R. R.

LANDER COUNTY—Continued.

Answood (Shoshone)—Continued.

Cambrian shales, quartzites and limestones.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 114, 1923.

De River (Amador, Austin, Yankee Blade). Ag, Au, Pb, Cu, Zn, As.

Station, N. C. R. R., in Toiyabe Range.

Paleozoic sediments cut by granite and capped by Tertiary volcanics.

Veins.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route: U. S. Geol. Survey Bull. 612, p. 170, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 199, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 114-117, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res., 1922, pt. 1, pp. 62, 326.

1923, pt. 1, p. 501.

1924, pt. 1, p. 438.

1925, pt. 1, p. 684.

1926, pt. 1, p. 540.

1928, pt. 1, p. 463.

Ekum. Ag, Au.

9 miles NW. Austin, N. C. R. R.

Paleozoic sediments cut by granite.

Veins, contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 117, 1923.

Min. Res. 1926, pt. 1, p. 540.

1928, pt. 1, p. 463.

cer. Au, Ag, Sb.

NE. Austin, N. C. R. R.

Paleozoic sediments, Tertiary volcanics.

Schrader, F. C.: Report in preparation.

U. S. G. S. Roberts Mountains topographic map.

LINCOLN COUNTY

anta (Silver Park, Silver Springs). Ag, Au, Cu, Pb, Ra.

About 40 miles NW. Pioche, U. P. R. R.

Quartzites and limestones overlain by Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 191, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 118, 1923.

(Caliente). Au, Ag, Cu, Pb.

8 miles NNW. Caliente, U. P. R. R.

Paleozoic sediments cut by basic dikes.

Veins.

Spurr, J. E., Geology of Nevada south of the Fortieth Parallel: U. S. Geol. Survey Bull. 208, pp. 37-48, 1903.

LINCOLN COUNTY—Continued.

Chief (Caliente)—Continued.

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Lincoln, Francis Church, Mining districts and mineral resources of
pp. 118-119, 1923.
Min. Res. 1925, pt. 1, p. 684.
1926, pt. 1, p. 541.
1928, pt. 1, p. 463.
U. S. G. S. Pioche topographic map.

Comet. Au, Ag, Pb, Cu, Zn, W.

- 14 miles SW. Pioche, U. P. R. R.
Paleozoic sediments cut by porphyry.
Veins, replacements.
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p. 119, 1923.
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1925, pt. 1, p. 684.
1926, pt. 1, p. 541.
1928, pt. 1, p. 463.
1929, pt. 1, p. 660.
U. S. G. S. Pioche topographic map.

Eagle Valley (Fay, State line). Au, Ag, Pb.

- 21 miles NW. Modena, Utah, U. P. R. R.
Tertiary volcanics.
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Lincoln, Francis Church, Mining districts and mineral resources of
p. 119, 1923.
U. S. G. S. Pioche topographic map.

Ferguson (Delamar). Au, Ag.

- 30 miles WSW. Caliente, U. P. R. R.
Paleozoic quartzite cut by basic dikes.
Veins, replacements.
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1928, pt. 1, p. 464.
U. S. G. S. Pioche topographic map.

Freiberg (Worthington). Au, Ag.

- 75 miles W. Pioche, U. P. R. R.
Rhyolite.
Veins.

LINCOLN COUNTY—Continued.

Sagehen (Worthington)—Continued.

- Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 120, 1923.
Min. Res. 1925, pt. 1, p. 685.

Sagehen. Pb, Ag.

- 100 miles N. Las Vegas, U. P. R. R.
Limestones and shales.
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1926, pt. 1, p. 541.
1928, pt. 1, p. 464.
1929, pt. 1, pp. 660-661.

Sagehen. Pb, Ag, Au, Cu.

- 7 miles WNW. Pioche, U. P. R. R.
Paleozoic sediments cut by dikes.
Veins, replacements.
Spurr, J. E., Geology of Nevada south of the Fortieth Parallel: U. S. Geol. Survey Bull. 208, pp. 38-45, 1903.
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1921, pt. 1, p. 386.
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1923, pt. 1, p. 501.
1924, pt. 1, p. 438.

U. S. G. S. Pioche and Highland topographic maps.

Sagehen (Pahranagat). Ag, Pb, Cu.

- 60 miles W. Caliente, U. P. R. R.
Paleozoic sediments.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.
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1928, pt. 1, p. 464.
1929, pt. 1, p. 661.

U. S. G. S. Pioche topographic map.

LINCOLN COUNTY—Continued.

Jack Rabbit (Bristol). Au, Pb, Ag, Cu, Mn.

16 to 20 miles NW. Pioche, U. P. R. R.

Paleozoic sediments cut by rhyolite.

Replacements, veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*
pp. 121-123, 1923.

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1928, pt. 1, p. 464.

1929, pt. 1, p. 661.

U. S. G. S. Bristol Range topographic map.

Lone Mountain. Ag, Pb.

16 miles W. Pioche, U. P. R. R.

Paleozoic sediments.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.

U. S. G. S. Pioche and Highland topographic maps.

Patterson (Cave Valley, Geyser). Au, Pb.50 miles SSE. Ely, N. N. R. R.; 45 miles N. Pioche, U. P. R. R., S. end of
Creek Mountains.

Cambrian quartzites, limestones and shales.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*
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Lincoln County, Nevada: Univ. of Nevada Bull., vol. 25, No. 3, July,
1931.

Min. Res. 1922, pt. 1, p. 327.

1923, pt. 1, p. 501.

1925, pt. 1, p. 685.

Pioche (Ely). Ag, Pb, Au, Cu, Zn, Mn, W.

Station, U. P. R. R.

Paleozoic sediments cut by dikes of quartz porphyry and diorite.

Replacements, veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 199, 200,Umpleby, J. B., *Manganese fluxing ore at Pioche, Nevada: E. & M. Eng.*
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che (Ely)—Continued.

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1926, pt. 1, pp. 158, 541-542.

1927, pt. 1, p. 188.

1928, pt. 1, p. 464.

1929, pt. 1, p. 661.

U. S. G. S. Pioche and Panaca (adv.) topographic maps.

verhorn. Ag, Ni.

23 miles NW. Pioche, U. P. R. R.

Limestones and shales cut by acid dikes.

Replacements.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 127-128, 1923.

U. S. G. S. Pioche topographic map.

n Piute. Ag, Pb, Cu, Zn.

In Timpahute Mountains, W. Lincoln County.

Paleozoic shales and limestone.

Lodes.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 128, 1923.

Min. Res. 1924, pt. 1, p. 439.

1925, pt. 1, p. 685.

1928, pt. 1, p. 464.

1929, pt. 1, p. 661.

ro. Mn.

24 miles E. Vigo, L. A. & S. L. R. R., in Mormon Range.

Pardee, J. T., and Jones, E. L., Jr., Deposits of manganese ore in Nevada: U. S. Geol. Survey Bull. 710, pp. 241-242, 1920.

U. S. G. S. Pioche topographic map.

ola. Pb, Zn, Cu, Ag.

One-fourth mile SE. Carp, U. P. R. R., in Mormon Range.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 128, 1923.

Min. Res. 1925, pt. 1, p. 685.

U. S. G. S. Pioche topographic map.

LYON COUNTY

nway. Au, Ag.

9 miles N. Schurz, S. P. R. R.

Granite, diorite, limestone.

Veins.

LYON COUNTY—Continued.

Benway—Continued.

Schrader, F. C.: Report in preparation.
U. S. G. S. Carson Sink topographic map.

Churchill. W.

Few miles N. Churchill, in basin on SE. slope Churchill Butte, S. P. R. R.
Volcanic rocks, granite.
Hess, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits.
United States: U. S. Geol. Survey Bull. 725, pp. 245-309, 1922.
U. S. G. S. Wabuska topographic map.

Como (Palmyra, Indian Springs). Au, Ag.

10 miles S. Dayton, S. P. R. R.
Lincoln, Francis Church, Mining districts and mineral resources of Lyon County, Nevada.
p. 130, 1923.
U. S. G. S. Carson topographic map.

Pine Nut Range. Au, Pl, Ag, Pb, Cu, Fe (not a mining district).

Tertiary volcanics, Triassic sediments.
Veins and placers.
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United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
U. S. G. S. Wabuska, Carson, Wellington, and Markleeville topographic maps.

Ramsey. Au, Ag.

17 miles SE. Clarks, S. P. R. R., on SE. flank Virginia Range.
Tertiary volcanics.
Veins, free gold.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of Nevada.
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Lyon County, Nevada.
pp. 130-131, 1923.
Min. Res. 1922, pt. 1, p. 328.
1923, pt. 1, p. 502.
1926, pt. 1, p. 542.
1928, pt. 1, p. 464.
U. S. G. S. Wabuska topographic map.

Red Mountain. Fe.

17 miles NE. Dayton, S. P. R. R.
Triassic sediments cut by granite.
Contact metamorphic.
Harder, E. C., Iron ores near Dayton, Nevada: U. S. Geol. Survey Bull. 430, pp. 240-246, 1910.
U. S. G. S. Wabuska topographic map.

Silver City (Chinatown, Dayton, Devils Gate, Gold Canyon). Au, Pl, Ag

Station, V. & T. R. R.
Tertiary volcanics.
Veins, placers.
Harder, E. C., Iron ores near Dayton, Nevada: U. S. Geol. Survey Bull. 430, pp. 240-246, 1910.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of Nevada.
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- er City (Chinatown, Dayton, Devils Gate, Gold Canyon)—Continued.
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- Smith, Alfred Merritt, The mines and mills of Silver City, Nevada: Nevada State Bureau of Mines and Mackay School of Mines Bull. No. 5, 1932.
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 1923, pt. 1, p. 502.
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 1928, pt. 1, p. 464.
 1929, pt. 1, pp. 661-662.
- U. S. G. S. Carson topographic map.
- poosa. Au, Ag, Cu.
 14 miles, S. Fernley, S. P. R. R.
 Tertiary volcanics.
 Veins.
- Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
- Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 132-133, 1923.
- Min. Res. 1922, pt. 1, p. 328.
 1923, pt. 1, p. 502.
 1924, pt. 1, p. 439.
 1926, pt. 1, p. 542.
 1928, pt. 1, p. 465.
 1929, pt. 1, p. 662.
- U. S. G. S. Wabuska topographic map.
- ngton (Ludwig, Mason). Cu, Pb, Au, Pl, Ag.
 Station N. C. B. R. R.
 Triassic sediments cut by granite.
 Contact metamorphic, placers.
- Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route: U. S. Geol. Survey Bull. 612, p. 184, 1915.
- Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191-197, 1917.
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- Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 133-137, 1923.
- Ferguson, H. G., Mining districts of Nevada: *Econ. Geology*, vol. 24, No. 2, March-April, 1929.
- Min. Res. 1922, pt. 1, p. 328.
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 1925, pt. 1, p. 686.
 1926, pt. 1, pp. 542-543.
 1928, pt. 1, pp. 465-466.
 1929, pt. 1, pp. 661-662.
- U. S. G. S. Wellington and Yerington district topographic maps.

MINERAL COUNTY

- ne (Fitting). Au, Ag, Pb, Cu.
 Station, S. P. R. R.
 Triassic sediments, Tertiary volcanics, veins, replacements.

MINERAL COUNTY—Continued.

Acme (Fitting)—Continued.

Lincoln, Francis Church, *op. cit.*

U. S. G. S. Hawthorne topographic sheet.

Aurora (Cambridge, Esmeralda). Au, Ag.

37 miles SW. Thorne, S. P. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, pp. 194, 199, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of*
pp. 137-138, 1923.

Ferguson, H. G., *Mining districts of Nevada: Econ. Geology*, vol. 24
March-April, 1929.

Min. Res. 1928, pt. 1, p. 466.

1929, pt. 1, p. 662.

U. S. G. S. Hawthorne topographic map.

Bovard (Copper Mountain, Rand). Au, Ag, Mn, Cu, Pb.

28 miles E. Schurz, S. P. R. R., 8 miles E. Rand.

Tertiary volcanics.

Veins, replacements.

Spurr, J. E., *Geology of Nevada south of the Fortieth Parallel: U.*
Survey Bull. 208, pp. 106-107, 1903.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of*
pp. 149-151, 1923.

Pardee, J. T., and Jones, E. L., Jr., *Deposits of manganese ore in*
U. S. Geol. Survey Bull. 710, p. 233, 1920.

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Min. Res. 1922, pt. 1, pp. 329-330.

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1924, pt. 1, pp. 440-441.

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1928, pt. 1, p. 406.

1929, pt. 1, p. 662.

U. S. G. S. Hawthorne topographic map.

Buena Vista (Basalt, Mount Montgomery, Orontal). Au, Ag, Pb, Cu, Zn.

Station, S. P. R. R., 1½ miles NE. Benton.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of*
pp. 140-141.

Schrader, F. C.: *Report in preparation.*

Min. Res. 1923, pt. 1, p. 303.

1924, pt. 1, p. 440.

1925, pt. 1, p. 687.

1926, pt. 1, p. 344.

1929, pt. 1, p. 662.

U. S. G. S. White Mountain topographic map.

Candelaria (Bollinger, Humboldt). Ag, Au, Pb, Cu, Zn.

Station, S. P. R. R.

Plutonic intrusions, Tertiary volcanics.

MINERAL COUNTY—Continued.

delaria (Belleville, Columbus)—Continued.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 195, 198, 1917.

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1924, pt. 1, pp. 433, 440.

1925, pt. 1, p. 687.

1926, pt. 1, p. 544.

1929, pt. 1, p. 663.

U. S. G. S. Hawthorne topographic map

ar Mountain (Bell, Omco, Simon). Ag, Au, Pb, Zn.

22 miles NE. Mina, S. P. R. R.

Triassic limestones, Tertiary lavas.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 138-140, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

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1925, pt. 1, pp. 686-687.

1926, pt. 1, p. 544.

1928, pt. 1, p. 466.

1929, pt. 1, pp. 662-663.

U. S. G. S. Tonopah topographic map.

t Walker (Mount Grant). Au, Ag.

Adjoins Walker Lake district on W.; W. slope Walker River Range.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 143, 1923.

U. S. G. S. Hawthorne topographic map.

field. Au, Ag, Cu, Pb.

15 miles NW. Mina, S. P. R. R.

Limestone cut by granodiorite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 144, 1923.

Min. Res. 1922, pt. 1, p. 329.

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1924, pt. 1, p. 440.

1925, pt. 1, p. 687.

1926, pt. 1, p. 544.

1928, pt. 1, p. 466.

1929, pt. 1, p. 663.

U. S. G. S. Hawthorne topographic map.

MINERAL COUNTY—Continued.

Granite (Mountain View, Reservation). *As, Ag, Pb, Cu.*

8 miles W. Schurz, S. P. R. R.

Granite capped by Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*, pp. 146-147, 1923.

U. S. G. S. Hawthorne topographic map.

Hawthorne (Lucky Boy, Pamlico). *Pb, Ag, As, Cu, W.*

7 miles SSW. Thorne, S. P. R. R.

Cambrian sediments cut by granite and diorite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

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1926, pt. 1, pp. 544-545.

1928, pt. 1, p. 498.

1929, pt. 1, p. 502.

U. S. G. S. Hawthorne topographic map.

King. *As, Ag, Pb.*

30 miles SE. Fallon, S. P. R. R.

Tertiary volcanics underlain by Mesozoic limestone, granite and gneiss.

Schrader, F. C., *The Chalk Mountain, Quartz Mountain, Gold Mountain, and King mining districts, Nevada*: U. S. Geol. Survey Paper 377, September 15, 1907.

U. S. G. S. Carson Sink topographic map.

Pine Grove (Blackhead, Wilson). *As, Pb, Ag.*

30 miles S. Tropicana, N. C. R. R. R.

Quartz monzonite cut by granite porphyry and veins by diorite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, p. 204, 1917.

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1923, pt. 1, p. 364.

U. S. G. S. Hawthorne and Wellington topographic maps.

Quinn. *As.*

7 miles NE. Quinn, S. P. R. R.

Veins.

Unpublished notes.

MINERAL COUNTY—Continued.

—Continued.

ss, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, p. 277, 1922.

S. G. S. Hawthorne and White Mountain topographic maps.

le (**Regent, Churchill County**). Au, Pl, Ag, Cu, Pb, W.

miles E. Schurz, S. P. R. R.

rtiary volcanics.

ins, placers.

radner, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 196, 198, 1917.

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rguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

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n. Res. 1922, pt. 1, p. 330.

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1925, pt. 1, p. 688.

1926, pt. 1, p. 545.

1928, pt. 1, p. 467.

1929, pt. 1, p. 663.

S. G. S. Carson Sink topographic map.

anyon. Ag, Au, Pb.

miles from Thorne.

n. Res. 1924, pt. 1, p. 441.

S. G. S. Hawthorne topographic map.

Fe (**Luning, Kincaid**). Au, Cu, Ag, Pb, Sb.

Luning, S. P. R. R.

crystalline limestones intruded by granitic rocks.

atact metamorphic.

ll, J. M., Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, pp. 157-171, 1915.

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rguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

n. Res. 1922, pt. 1, p. 330.

1924, pt. 1, p. 441.

1925, pt. 1, p. 688.

1928, pt. 1, p. 467.

1929, pt. 1, pp. 663-664.

S. G. S. Hawthorne topographic map.

Star (**Black Mountain, Gold Range, Marietta, Mina**). Au, Cu, Ag, Pb, W.

ld Range and Mina in vicinity of Mina, S. P. R. R.; Black Mountain or Marietta near Marietta, 26 miles SW. Mina, in Excelsior Mountains.

ozoic sediments, intruded and capped by volcanic rocks.

ins, contact metamorphic.

MINERAL COUNTY—Continued.

Silver Star (Black Mountain, Gold Range, Marietta, Mina)—Continued.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals.

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Schutte, C. N., Occurrence of quicksilver ore bodies: A. I. M. Pub. 533, p. 45, July, 1931.

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1924, pt. 1, pp. 440-441.

1925, pt. 1, pp. 422, 488.

1926, pt. 1, p. 545.

1927, pt. 1, pp. 425-426.

1928, pt. 1, pp. 423, 467.

1929, pt. 1, p. 469.

U. S. G. S. Hawthorne topographic map.

Sodaville (Pilot Mountain), Co. Min., Hg. W., Ag. Ar., Pl. Pl.

15 miles E. Sodaville, S. P. R. R.

Mesozoic sediments cut by granite and capped by Tertiary volcanic, contact metamorphic, gneisses.

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1925, pt. 1, pp. 422, 488.

1926, pt. 1, p. 545.

1928, pt. 1, pp. 474, 467.

1929, pt. 1, p. 469.

U. S. G. S. Hawthorne and Hawthorne topographic maps.

Sulphide, Ag. W.

15 miles SE. Hawthorne, which is 7 miles SE. Thoreau, S. P. R. R.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada: U. S. Geol. Survey Bull. 725, pp. 147-148, 1923.

U. S. G. S. Hawthorne topographic map.

Sulphide (Big Springs), Ag. Ag.

Between Eagle-Valley, Nevada, and Hawthorne, Mineral Co.

Quartzite dikes.

Tungsten.

Schrader, F. C., Report in preparation.

U. S. G. S. Hawthorne topographic map.

MINERAL COUNTY—Continued.

Lake (Buckley, Cat Creek). Au, Ag, Cu.

Walker Lake on E. slope Walker River or Wassuk Range.
anodiorite.

ns.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 156-157, 1923.

n. Res. 1922, pt. 1, p. 330.

1924, pt. 1, p. 441.

S. G. S. Hawthorne topographic map.

gton. Cu, Au, Ag.

miles S. Yerington, N. C. B. R. R., on E. Fork Walker River.

coln, Francis Church, Mining districts and mineral resources of Nevada,
p. 157, 1923.

n. Res. 1929, pt. 1, p. 664.

S. G. S. Hawthorne topographic map.

y Flat. Cu, Ag, Au.

miles SE. Hawthorne, which is 7 miles SW. Thorne, S. P. R. R.

nite limestone contact.

ns.

coln, Francis Church, Mining districts and mineral resources of Nevada,
p. 157, 1923.

S. G. S. Hawthorne topographic map.

NYE COUNTY

ce. Au, Ag.

miles ESE. Goldfield, T. & G. R. R.

eozoic sediments cut by granite and capped by Tertiary eruptives.

ns.

coln, Francis Church, Mining districts and mineral resources of Nevada,
p. 158, 1923.

n. Res. 1926, pt. 1, p. 546.

S. G. S. Kawich topographic map.

ead. Ag, Au.

miles E. Tonopah, T. & G. R. R.

eozoic sediments capped by Tertiary eruptives.

ns, replacements.

coln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 158-159, 1923.

n. Res. 1922, pt. 1, p. 332.

S. G. S. Morey Peak topographic (adv. 1933) map.

Au, Ag.

miles by road NE. Mina, S. P. R. R.

tiary eruptives and later lake beds.

ns.

coln, Francis Church, Mining districts and mineral resources of Nevada,
p. 159, 1923.

n. Res. 1923, pt. 1, p. 504.

1928, pt. 1, p. 467.

S. G. S. Tonopah topographic map.

ten. Au, Ag.

miles E. Tonopah, T. & G. R. R.

tiary volcanics.

ns.

grader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

NYE COUNTY—Continued.

Bellehelen—Continued.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 159-160, 1923.

Min. Res. 1922, pt. 1, pp. 330-331.

1923, pt. 1, p. 504.

1924, pt. 1, p. 441.

1925, pt. 1, pp. 688-689.

1926, pt. 1, p. 546.

1928, pt. 1, p. 467.

1929, pt. 1, p. 664.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Belmont (Philadelphia, Silver Bend). Ag, Pb, Cu, Hg, Au.

50 miles NNE. Tonopah, T. & G. R. R.

Paleozoic sediments cut by granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, pp. 192, 198, 199.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 160-161, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology
No. 2, March-April, 1929.

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1918, pt. 1, p. 251.

1919, pt. 1, p. 404.

1920, pt. 1, pp. 329-330.

1921, pt. 1, pp. 389-390.

1922, pt. 1, pp. 330-331.

1923, pt. 1, p. 505.

1928, pt. 1, pp. 275-276.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Big Dune (Lee). Au, Cu.

NW. Leeland, T. & T. R. R., in Amargosa Desert.

Cambrian sediments.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources
p. 173, 1923.

U. S. G. S. Furnace Creek topographic map.

Bruner (Phonolite). Au, Ag.

50 miles NE. Luning, S. P. R. R.

Rhyolite and andesite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 161-162, 1923.

Min. Res. 1922, pt. 1, p. 331.

1923, pt. 1, p. 504.

1924, pt. 1, p. 442.

1925, pt. 1, p. 689.

1929, pt. 1, p. 664.

U. S. G. S. Tonopah topographic map.

Bullfrog (Beatty, Pioneer, Rhyolite). Au, Ag, Cu, Pb, Hg.

Station T. & T. R. R.

NYE COUNTY—Continued.

Bullfrog (Beatty, Pioneer, Rhyolite)—Continued.

Tertiary volcanics.

Veins.

Knopf, Adolph, Some cinnabar deposits in western Nevada: U. S. Geol. Survey Bull. 620, pp. 62-68, 1916.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 195, 196, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 162-163, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 331.

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1924, pt. 1, p. 442.

1925, pt. 1, p. 689.

1926, pt. 1, p. 546.

1928, pt. 1, pp. 467-468.

1929, pt. 1, p. 664.

U. S. G. S. Bullfrog Special and Furnace Creek topographic maps.

Cactus Springs. Au, Ag.

24 miles E. Goldfield, T. & G. R. R., NW. end Cactus Range.

Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 164, 1923.

U. S. G. S. Kawich topographic map.

Ford. Au, Ag.

About 35 miles E. Tonopah, T. & G. R. R.

Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 165, 1923.

Verde (Golden, Republic). Au, Pl, Ag, Pb, Cu.

32 miles E. Luning, S. P. R. R.; 42 miles NE. Sodaville.

Tertiary volcanics.

Veins, placers.

Spurr, J. E., Geology of Nevada south of the Fortieth Parallel: U. S. Geol. Survey Bull. 208, pp. 93-97, 1903.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 165-166, 1923.

Min. Res. 1922, pt. 1, p. 331.

1925, pt. 1, p. 689.

1926, pt. 1, p. 546.

U. S. G. S. Tonopah topographic map.

Culant. Au, Pb, Cu.

E. Culant in NE. Nye County.

Limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 166, 1923.

NYE COUNTY—Continued.

Danville. Au, Ag.

In Monitor Range, N. Nye County.

Limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 166, 1923.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Eden (Gold Belt). Au, Ag.

55 miles E. Tonopah, T. & G. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 166, 1923.

Min. Res. 1928, pt. 1, p. 468.

U. S. G. S. Kawich topographic map.

Ellendale. Au, Ag, Cu.

Few miles E. Tonopah, T. & G. R. R.

Tertiary volcanics.

Veins, stringers.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 167, 1923.

U. S. G. S. Tonopah topographic map.

Fairplay (Atwood, Goldyke). Au, Ag, W, Cu, Pb.

32 miles NE. Luning, S. P. R. R.

Granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 167, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 331.

1923, pt. 1, p. 505.

1925, pt. 1, p. 689.

1926, pt. 1, p. 546.

1929, pt. 1, p. 664.

U. S. G. S. Tonopah topographic map.

Fluorine (Bare Mountain, Telluride). Hg, Au, Ag.

6 miles E. Beatty, T. & T. R. R.

Paleozoic sediments intruded by pegmatites and monzonite porphyries.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 167-169, 1923.

U. S. G. S. Furnace Creek topographic map.

Gold Crater. Au, Ag.

27 miles SE. Goldfield, T. & G. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

NYE COUNTY—Continued.

d Crater—Continued.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 169, 1923.

U. S. G. S. Kawich topographic map.

den Arrow (Blakes Camp). Au, Ag.

About 30 miles ESE. Tonopah, and 50 miles NE. Goldfield, T. & G. R. R.

Tertiary eruptives.

Veins, contact metamorphic.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 169-170, 1923.

U. S. G. S. Kawich topographic map.

pevine. Au.

22 miles W. Beatty, T. & T. R. R.

Rhyolite.

Veins.

U. S. G. S. Lida topographic map.

Tonopah (Silverzone, Volcano). Au, Ag, Hg.

20 miles E. Tonopah, T. & G. R. R.

Tertiary volcanics.

Veins.

Spurr, J. E., Ore deposits of Tonopah and neighboring districts, Nevada:
U. S. Geol. Survey Bull. 213, p. 87, 1903.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 170, 1923.

Min. Res. 1922, pt. 1, p. 331.

1923, pt. 1, p. 505.

1924, pt. 1, p. 442.

1925, pt. 1, p. 689.

1926, pt. 1, p. 546.

1928, pt. 1, pp. 277, 468.

1929, pt. 1, p. 664.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Tonopah (Gold Park). Au, Ag, Cu, Pb.

44 miles SE. Austin, N. C. R. R.; 34 miles from Leslie, N. C. R. R., partly
in Lander County.

Paleozoic sediments, granite porphyry and Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 170-171, 1923.

U. S. G. S. Tonopah topographic map.

Person Canyon (Concordia, Green Isle). Au, Ag.

70 miles NNE. Tonopah, T. & G. R. R.

Paleozoic sediments cut by porphyry.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 171-172, 1923.

U. S. G. S. Tonopah topographic map.

t. Ag, Pb, Zn.

45 miles N. Millers, T. & G. R. R.

Slate and limestone.

NYE COUNTY—Continued.

Jett—Continued.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 172, 1923.

U. S. G. S. Tonopah topographic map.

Johnnie. Au, Pl, Ag, Pb.25 miles NE. Death Valley in NW. end Spring Mountain Range;
SSE. Amargosa.

Paleozoic sediments.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.Lincoln, Francis Church, Mining districts and mineral resources of
pp. 172-173, 1923.

Min. Res. 1922, pt. 1, p. 331.

1923, pt. 1, p. 505.

1924, pt. 1, p. 442.

1925, pt. 1, p. 689.

1926, pt. 1, p. 546.

1928, pt. 1, p. 468.

1929, pt. 1, p. 665.

U. S. G. S. Furnace Creek topographic map.

Kawich (Gold Reed). Au, Hg.

54 miles E. Goldfield, T. & G. R. R.

Monzonite porphyry and rhyolite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.Lincoln, Francis Church, Mining districts and mineral resources of
p. 173, 1923.

U. S. G. S. Kawich topographic map.

Lodi (Ellsworth, Mammoth, Marble). Ag, Au, Pb, Cu, W.

45 miles NNE. Luning, S. P. R. R., in Mammoth Range.

Granite and limestone.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.Another gold excitement now developing in Nevada: Salt Lake
Review, April 30, 1921, p. 20.Lincoln, Francis Church, Mining districts and mineral resources of
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1923, pt. 1, p. 505.

1924, pt. 1, p. 442.

1925, pt. 1, p. 689.

1926, pt. 1, pp. 546-547.

1928, pt. 1, pp. 468, 423.

U. S. G. S. Tonopah topographic map.

Manhattan. Au, Pl, Ag, As.

45 miles N. Tonopah, T. & G. R. R.

Paleozoic sediments cut by granite and diorite and capped by
volcanics.

Veins, replacements, placers.

NYE COUNTY—Continued.

Manhattan—Continued.

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1921, pt. 1, p. 390.

1922, pt. 1, p. 331.

1923, pt. 1, p. 505.

1924, pt. 1, p. 442.

1925, pt. 1, pp. 689-690.

1926, pt. 1, p. 547.

1928, pt. 1, pp. 468-469.

1929, pt. 1, p. 665.

U. S. G. S. Manhattan and vicinity and Tonopah topographic maps.

North Twin River). Au, Ag, Pb, Cu.

5 miles S. Austin, N. C. R. R.; 105 miles N. Tonopah, T. & G. R. R.

Limestone and slate.

Feins, pockets.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 177-178, 1923.

U. S. G. S. Tonopah topographic map.

Min. Res. 1908, pt. 1, p. 498.

1909, pt. 1, p. 421.

1910, pt. 1, p. 527.

1911, pt. 1, p. 690.

1912, pt. 1, p. 38.

1913, pt. 1, p. 835.

1914, pt. 1, p. 701.

1915, pt. 1, p. 646.

1916, pt. 1, p. 492.

1922, pt. 1, p. 331.

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1924, pt. 1, p. 442.

y. Ag, Au, Pb.

W. Morey in Hot Creek Range.

Granite.

Feins.

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Min. Res. 1922, pt. 1, p. 331.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Northumberland. Ag.

W. Northumberland, in N. part of county, in Toquima Range.

Granite porphyry.

Feins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 178, 1923.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

NYE COUNTY—Continued.

Oak Springs. Au, Ag, Cu, W, Mo.

80 miles SW. Caliente, U. P. R. R.

Paleozoic sediments cut by granite and capped by Tertiary volcanic
Veins.Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 195,
1917.Lincoln, Francis Church, Mining districts and mineral resources
pp. 178-179, 1923.

U. S. G. S. Kawich topographic map.

Reveille. Ag, Pb, Cu, Au.

70 miles E. Tonopah, T. & G. R. R.

Paleozoic sediments capped by Tertiary eruptives.
Veins.Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.Lincoln, Francis Church, Mining districts and mineral resources
pp. 179-180, 1923.

Min. Res. 1922, pt. 1, p. 332.

1923, pt. 1, p. 505.

1924, pt. 1, p. 442.

1926, pt. 1, p. 547.

1928, pt. 1, p. 469.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

Round Mountain. Au, Pl, Ag, Pb, W.

60 miles N. Tonopah, T. & G. R. R.

Paleozoic sediments, Tertiary volcanics.
Veins, placers.Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals
United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 196,Lincoln, Francis Church, Mining districts and mineral resources
pp. 180-181, 1923.Ferguson, H. G., The mining districts of Nevada: Econ. Geology
No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, p. 332.

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1924, pt. 1, p. 442.

1925, pt. 1, p. 690.

1926, pt. 1, pp. 547-548.

1928, pt. 1, p. 469.

1929, pt. 1, p. 665.

U. S. G. S. Tonopah topographic map.

San Antone (Royston, San Antonio). Ag, Au, Pb, Cu.

20 to 28 miles S. and SE. Tonopah, T. & G. R. R.

Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 181-182, 1923.

Min. Res. 1922, pt. 1, p. 332.

1923, pt. 1, p. 506.

1924, pt. 1, p. 442.

1925, pt. 1, p. 690.

1926, pt. 1, p. 548.

1928, pt. 1, p. 469.

1929, pt. 1, p. 665.

U. S. G. S. Tonopah topographic map.

NYE COUNTY—Continued.

erbow. Au, Ag.

46 miles E. Goldfield, T. & G. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 192, 194, 196, 197, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 182-183, 1923.

Min. Res. 1929, pt. 1, p. 665.

U. S. G. S. Kawich topographic map.

ish Belt (Barcelona). Hg, Ag.

65 miles NE. Tonopah, T. & G. R. R., between Belmont and Manhattan.

Granite and shale.

Veins.

Consolidated Spanish Belt mine soon will be producing: Salt Lake Mining Review, April 30, 1921, p. 26.

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Min. Res. 1928, p. 276.

U. S. G. S. Tonopah topographic map.

ewall Mountain. Au, Ag.

17 miles SSE. Goldfield, T. & G. R. R.

Paleozoic sediments cut by granite, capped by Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 183, 1923.

Min. Res. 1926, pt. 1, p. 548.

U. S. G. S. Lida topographic map.

uride. (See Fluorine.)

cha (Monte Cristo). Au, Ag.

20 miles E. Bonnie Clare; 50 miles SE. Goldfield, T. & G. R. R.

Tertiary rhyolite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 183-184, 1923.

Min. Res. 1923, pt. 1, p. 506.

1929, pt. 1, p. 665.

U. S. G. S. Kawich topographic map.

pah. Ag, Au, Pb, Cu, W.

Station T. & G. R. R.

Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 190, 192, 195, 196, 197, 198, 1917.

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NYE COUNTY—Continued.

Tonopah—Continued.

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Geology and ore deposits of the Tonopah mining district, Ne

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Nevada: Report in preparation.

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1924, pt. 1, pp. 435, 443-444.

1925, pt. 1, pp. 681, 690-692.

1926, pt. 1, pp. 536, 548-551.

1928, pt. 1, pp. 460, 469-471.

1929, pt. 1, pp. 657, 666-667.

U. S. G. S. Tonopah and Tonopah Special topographic maps.

Trappmans. Ag, Au.

40 miles ESE. Goldfield, T. & G. R. R.

Granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful mine
United States: U. S. Geol. Survey Bull. 624, pp. 197, 198, 19

Lincoln, Francis Church, Mining districts and mineral resources
p. 193, 1923.

U. S. G. S. Kawich topographic map.

Troy (Irwin Canyon, Nyala). Ag, Au, Pb.

About 30 miles S. Currant P. O.

Sedimentary rocks.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 193-194, 1923.

Min. Res. 1925, pt. 1, p. 692.

1926, pt. 1, p. 551.

Twin River. Ag.

50 miles S. Austin, N. C. R. R.

Slate.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources
pp. 194-195, 1923.

U. S. G. S. Tonopah topographic map.

Tybo (Hot Creek, Keystone). Ag, Au, Pb, Cu, Sb, Mn.

70 miles NE. Tonopah, T. & G. R. R.

Paleozoic sediments and Tertiary volcanics.

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful mine
United States: U. S. Geol. Survey Bull. 624, pp. 198, 199, 19

Lincoln, Francis Church, Mining districts and mineral resources
p. 195, 1923.

Ferguson, H. G.: Report in preparation.

Min. Res. 1925, pt. 1, p. 692.

1926, pt. 1, p. 551.

1928, pt. 1, p. 471.

1929, pt. 1, p. 667.

U. S. G. S. Morey Peak topographic (adv. 1933) map.

NYE COUNTY—Continued.

- on (Berlin, Ione).** Hg, Au, Pl, Ag, Pb, Zn, Cu, W.
60 miles SW. Austin, N. C. R. R., W. slope Shoshone Range; 40 miles NE.
Luning, S. P. R. R.
Carboniferous sediments and Tertiary volcanics.
Veins, placers.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 195, 198,
1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 195-197, 1923.
Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24,
No. 2, March-April, 1929.
Min. Res. 1922, pt. 1, p. 335.
1923, pt. 1, p. 508.
1924, pt. 1, p. 444.
1925, pt. 1, p. 692.
1926, pt. 1, p. 551.
1928, pt. 1, pp. 277, 471.
1929, pt. 1, p. 667.
U. S. G. S. Tonopah topographic map.
- Wahmonie.** Ag, Au.
30 miles E. Beatty, T. & T. R. R.
Veins.
Wahmonie, Nevada: Eng. & Min. Jour., vol. 125, No. 1, March 17, 1928,
p. 467.
Min. Res. 1928, pt. 1, pp. 471-472.
U. S. G. S. Furnace Creek topographic map.
- Washington.** Ag, Pb.
28 miles SSW. Austin, N. C. R. R., on Lander County border.
Paleozoic sediments.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 197, 1923.
Min. Res. 1909, pt. 1, p. 415.
1915, pt. 1, p. 638.
1918, pt. 1, p. 256.
1919, pt. 1, p. 410.
1920, pt. 1, p. 325.
- Wilmington (O'Briens).** Au, Ag.
20 miles E. Cuprite.
Tertiary volcanics.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 197-198, 1923.
U. S. G. S. Kawich topographic map.
- Low Creek.** Au, Ag, Cu.
90 miles SW. Ely, N. N. R. R.; 90 miles E. Tonopah, T. & G. R. R., near
S. end Railroad Valley.
Paleozoic sediments and Tertiary eruptives.

NYE COUNTY—Continued.

Willow Creek—Continued.

Veins, replacements.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 198, 1923.

Min. Res. 1924, pt. 1, p. 444.

1925, pt. 1, p. 692.

1928, pt. 1, p. 472.

Wilson. Ag, Au.

38 miles ESE. Goldfield, T. & G. R. R.

Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 198-199, 1923.

U. S. G. S. Kawich topographic map.

ORMSBY COUNTY

Carson River. Cu, Au, Ag, Hg, As.

9 miles E. Carson City, V. & T. R. R.

Min. Res. 1914, pt. 1, p. 707.

1915, pt. 1, p. 650.

1916, pt. 1, p. 495.

1918, pt. 1, p. 256.

1921, pt. 1, p. 393.

1922, pt. 1, p. 62.

1923, pt. 1, p. 508.

1924, pt. 1, pp. 141, 445.

1925, pt. 1, p. 692.

1929, pt. 1, p. 667.

U. S. G. S. Carson topographic map.

Delaware (Sullivan). Cu, Au, Ag, Pb.

S. of V. & T. R. R. in neighborhood of Brunswick Canyon, E.
County.

Andesite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 199-200, 1923.

Min. Res. 1924, pt. 1, p. 445.

1926, pt. 1, p. 551.

1929, pt. 1, p. 667.

U. S. G. S. Carson topographic map.

Voltaire (Washoe, Eagle Valley). Ag, Au, Pl, Cu, As.

W. Carson City, V. & T. R. R., in foothills Sierra Nevada.

Triassic schists intruded by Cretaceous granodiorite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 200-201, 1923.

Min. Res. 1910, pt. 1, p. 530.

1911, pt. 1, pp. 696-697.

1917, pt. 1, p. 293.

1918, pt. 1, p. 257.

1919, pt. 1, p. 410.

1923, pt. 1, p. 508.

1925, pt. 1, p. 692.

1928, pt. 1, p. 472.

U. S. G. S. Carson topographic map.

PERSHING COUNTY

- lope (Cedar).** Pb, Ag, Zn, Au, Cu, Hg, As, Sb.
20 miles W. Mill City, S. P. R. R., W. P. R. R., in Trinity Range.
Triassic slate intruded by dikes of rhyolite porphyry.
Veins.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 195, 199, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 201, 1923.
Min. Res. 1922, pt. 1, p. 335.
1924, pt. 1, pp. 40, 445.
1925, pt. 1, pp. 692-693.
1926, pt. 1, p. 551.
1928, pt. 1, pp. 270, 472.
1929, pt. 1, p. 667.
U. S. G. S. Lovelock (adv.) topographic map.
- Knob.** Sb.
N. end Humboldt Lake Range.
Jurassic calcareous shale.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 201-202, 1923.
U. S. G. S. Lovelock (adv.) topographic map.
- a Vista (Unionville).** Ag, Au, Pb, Cu, Sb, Fe.
25 miles by road S. Mill City, S. P. R. R., on E. slope Humboldt Range.
Triassic sedimentary rocks cut by granite intrusives and covered in part by Tertiary volcanic rocks and Quaternary sediments and wash.
Replacements.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 202-203, 1923.
Schrader, F. C., Buena Vista iron deposits in Pershing and Churchill Counties, Nevada: Trans. for publication by Nevada State Bureau of Mines.
Min. Res. 1922, pt. 1, p. 336.
1923, pt. 1, p. 509.
1924, pt. 1, p. 446.
1925, pt. 1, p. 693.
1926, pt. 1, p. 552.
1929, pt. 1, p. 669.
U. S. G. S. Lovelock (adv.) topographic map.
- er Valley (Ragged Top).** W. Cu.
10 miles W. Toulon, siding on S. P. R. R.
Limestone, cut by quartz diorite dikes.
Contact metamorphic.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 203-204, 1923.
U. S. G. S. Lovelock (adv.) topographic map.
- (Eye Patch).** Ag, Au, Cu, Pb, W.
W. flank Humboldt Range, central Pershing County.
Limestone cut by diabase dike.
Veins, contact metamorphic.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 204-205, 1923.
Min. Res. 1924, pt. 1, p. 446.
1929, pt. 1, p. 668.
U. S. G. S. Lovelock (adv.) topographic map.

PERSHING COUNTY—Continued.

Farrell (Stone House). Au.

45 miles NW. Lovelock, S. P. R. R.

Tertiary rhyolite.

Veins and lenses.

Lincoln, Francis Church, Mining districts and mineral resources
p. 205, 1923.Increasing gold prospecting embraces entire world; many st
reported: Eng. & Min. Jour., vol. 132, No. 4, August 24, 1931

U. S. G. S. Lovelock (adv.) topographic map.

Gold Banks. Hg, Au, Ag.

40 miles S. Winnemucca, S. P. R. R., W. P. R. R.

Quartz porphyry.

Replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful miner
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.Lincoln, Francis Church, Mining districts and mineral resources o
pp. 205-206, 1923.Schuette, C. N., Occurrence of quicksilver ore bodies: A. I. M. M
Pub. 335, p. 40, July, 1931.

Min. Res. 1925, pt. 1, p. 47.

U. S. G. S. Sonoma Range (adv.) topographic map.

Haystack. Au.

7 miles S. Jumbo, W. P. R. R.

Granite and quartzite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources o
p. 206, 1923.

Min. Res. 1929, pt. 1, p. 668.

U. S. G. S. Lovelock (adv.) topographic map.

Imlay (Humboldt, Prince Royal, Eldorado). Ag, Au, Pb, Cu, Hg.

6 miles S. Imlay, S. P. R. R.; 4 miles E. Humboldt, S. P. R. R.

Jurassic sediments cut by granite and capped by Tertiary volcanic

Veins, replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful miner
United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.Lincoln, Francis Church, Mining districts and mineral resources o
pp. 206-207, 1923.Schuette, C. N., Occurrence of quicksilver ore bodies: A. I. M. M
Pub. 335, p. 40, 1931.

Min. Res. 1926, pt. 1, p. 552.

U. S. G. S. Lovelock (adv.) topographic map.

Indian. Ag, Au.

Indian Canyon, E. flank Humboldt Range.

Placers, veins.

Lincoln, Francis Church, Mining districts and mineral resources o
p. 207, 1923.

U. S. G. S. Lovelock (adv.) topographic map.

Iron Hat. Pb, Ag, Cu.

20 miles S. Imlay, S. P. R. R., E. slope Sonoma Range.

Limestone.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources o
p. 207, 1923.

U. S. G. S. Sonoma Range (adv.) topographic map.

PERSHING COUNTY—Continued.

- sey.** Ag, Pb, Hg.
43 miles SW. Battle Mountain, S. P. R. R.; 32 miles W. Watts, N. C. R. R.
Quartzite and porphyry.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 207-208, 1923.
Schuette, C. N., Occurrence of quicksilver ore bodies: A. I. M. M. E. Tech.
Pub. 335, pp. 42-43, July, 1931. (Ruby group of claims in Jersey Valley,
55 miles S. Battle Mountain.)
Min. Res. 1922, pt. 1, p. 335.
1923, pt. 1, p. 509.
1924, pt. 1, p. 445.
1925, pt. 1, p. 693.
1926, pt. 1, p. 552.
1928, pt. 1, p. 472.
1929, pt. 1, p. 668.
U. S. G. S. Sonoma Range (adv.) topographic map.
- niper Range.** W, Cu, Ag, Au.
20 miles NW. Huxley, S. P. R. R.; 40 miles SW. Lovelock, S. P. R. R.
Sediments intruded by quartz diorite.
Contact metamorphic.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 199, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 208, 1923.
U. S. G. S. Granite Range topographic map.
- nnedy.** Au, Ag, Pb.
55 miles SW. Winnemucca, S. P. R. R., W. P. R. R.
Triassic sediments cut by granite and capped by Tertiary volcanics.
Veins.
Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western
United States, Part B, The Overland Route, with a side trip to Yellow-
stone Park: U. S. Geol. Survey Bull. 612, p. 175, 1915.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 208-209, 1923.
Min. Res. 1922, pt. 1, p. 335.
1923, pt. 1, p. 509.
1924, pt. 1, p. 445.
1926, pt. 1, p. 552.
1928, pt. 1, p. 472.
U. S. G. S. Sonoma Range (adv.) topographic map.
- ring (Lovelock, Willard).** Ag, Au, W, Fe, Hg.
10 miles NE. Lovelock, S. P. R. R., in Humboldt Range.
Limestones, rhyolite and basalt dikes.
Veins, contact metamorphic.
Ransome, F. L., Notes on some mining districts in Humboldt County,
Nevada: U. S. Geol. Survey Bull. 414, pp. 12, 58, 1909.
Hess, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits of
the United States: U. S. Geol. Survey Bull. 725, pp. 246, 294, 1922.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, pp. 190, 194, 195, 198,
1917.

PERSHING COUNTY—Continued.

Loring (Lovelock, Willard)—Continued.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 209, 1923.

Min. Res. 1924, pt. 1, p. 445.

1927, pt. 1, p. 66.

1928, pt. 1, p. 273.

U. S. G. S. Lovelock (adv.) topographic map.

Mill City (Central). W, Ag, Cu.

7 miles NW. Mill City, S. P. R. R., on SE. slope Eugene Mountain.
Sediments intruded by porphyritic rocks and granodiorite.

Replacements, contact metamorphic.

Hess, F. L., and Larsen, E. S., Contact metamorphic tungsten deposits

United States: U. S. Geol. Survey Bull. 725, pp. 295-300, 1922.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 209-210, 1923.

Carpenter, Jay A., Mineral resources of southern Nevada: Bull. N.
Bur. Mines, vol. 1, No. 1, p. 19, 1929.

Min. Res. 1917, pt. 1, pp. 943-944.

1924, pt. 1, p. 466.

1925, pt. 1, p. 612.

1927, pt. 1, p. 425.

1928, pt. 1, p. 123.

U. S. G. S. Lovelock (adv.) topographic map.

Mineral Basin. Fe, Hg.

25 miles SE. Lovelock, S. P. R. R.

Triassic sediments cut by granite intrusions.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 210, 1923.

U. S. G. S. Carson Sink and Lovelock (adv.) topographic maps.

Muttleberry. Ag, Pb, Cu.

9 miles ESE. Lovelock, S. P. R. R.

Triassic and Jurassic sediments capped by Tertiary volcanics in place

Lincoln, Francis Church, Mining districts and mineral resources of
p. 211, 1923.

U. S. G. S. Lovelock (adv.) topographic map.

Nightingale. W.

E. side Lake Winnemucca, in Nightingale Range.

Sediments and quartz monzonite.

Contact metamorphic.

Lincoln, Francis Church, Mining districts and mineral resources of
pp. 211-212, 1923.

Min. Res. 1925, pt. 1, p. 612.

1927, pt. 1, p. 426.

1928, pt. 1, p. 123.

U. S. G. S. Granite Range topographic map.

Placerites (Rabbit Hole). Au, Pl, Cu.

50 miles N. Lovelock, S. P. R. R.

Placers.

Lincoln, Francis Church, Mining districts and mineral resources of
p. 212, 1923.

Min. Res. 1929, pt. 1, p. 668.

U. S. G. S. Lovelock (adv.) topographic map.

Relief (Antelope Springs). Hg, Ag, Au, Sb.

22 miles E. Lovelock, S. P. R. R.

Triassic limestone.

PERSHING COUNTY—Continued.

Chief (Antelope Springs)—Continued.

- Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 212-213, 1923.
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1928, pt. 1, pp. 270-273.
U. S. G. S. Lovelock (adv.) topographic map.
- Chesler (Nenzel, Oreana). Au, Pl, Ag, Pb, Cu, Sb.
9 miles E. Oreana, S. P. R. R.
Triassic volcanics.
Veins and placers.
Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 178, 1915.
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Min. Res. 1922, pt. 1, pp. 335-336.
1923, pt. 1, p. 509.
1924, pt. 1, pp. 445-446.
1925, pt. 1, p. 693.
1926, pt. 1, p. 552.
1928, pt. 1, pp. 472-473.
1929, pt. 1, p. 668.
U. S. G. S. Rochester Special and Lovelock (adv.) topographic maps.
- Chesler (Sawtooth). Ag, Au, Pl, Cu, Pb.
10 miles SE. Sulphur, W. P. R. R.
Jurassic sediments and Tertiary volcanics.
Veins, placers.
Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 177, 1915.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 191, 197, 198, 199, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 215, 1923.
Min. Res. 1922, pt. 1, p. 336.
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1925, pt. 1, p. 693.
1926, pt. 1, p. 552.
1929, pt. 1, p. 668.
U. S. G. S. Lovelock (adv.) topographic map.
- Chesler (Humboldt Range). Ag, Au, Pl.
W. flank Humboldt Range, in central Pershing County.
Triassic limestone.

PERSHING COUNTY—Continued.

Sacramento—Continued.

Veins and placers.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 215-216, 1923.

Min. Res. 1926, pt. 1, p. 552.

U. S. G. S. Lovelock (adv.) topographic map.

San Jacinto. Ag, Pb, As.

9 miles NW. Rye Patch, S. P. R. R.

Slate and granite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 216, 1923.

Min. Res. 1926, pt. 1, p. 552.

U. S. G. S. Lovelock (adv.) topographic map.

Scossa. Au.

50 miles N. Lovelock, S. P. R. R.

Slates and schists interbedded with sandstones and limestones.

Veins.

Jones, J. C., Smith, A. M., and Stoddard, Carl, The preliminary survey of the Scossa mining district, Pershing County, Nevada: Univ. of Nevada Bull., vol. 25, No. 4, June, 1931.

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U. S. G. S. Lovelock (adv.) topographic map.

Seven Troughs. Au, Ag, Cu, Pb.

30 miles NW. Lovelock, S. P. R. R.

Tertiary volcanics.

Veins.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, pp. 179-180, 1915.

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1925, pt. 1, p. 693.

1926, pt. 1, p. 552.

1928, pt. 1, p. 473.

1929, pt. 1, p. 668.

U. S. G. S. Lovelock (adv.) topographic map.

Sierra (Sunshine, Dun Glen, Chafey, Oro Fino). Au, Pl, Ag, Pb, Cu.

10 miles SE. Mill City, S. P. R. R.

Limestone cut by volcanics.

Veins and placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of Nevada: United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 197, 198.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 217-218, 1923.

PERSHING COUNTY—Continued.

ra (Sunshine, Dun Glen, Chafey, Oro Fino)—Continued.

Min. Res. 1922, pt. 1, p. 336.

1923, pt. 1, p. 509.

1924, pt. 1, p. 446.

1925, pt. 1, p. 693.

1926, pt. 1, p. 552.

1928, pt. 1, p. 473.

1929, pt. 1, p. 668.

U. S. G. S. Sonoma Range (adv.) topographic map.

ng Valley (Fitting, American Canyon). Au, Pl, Ag, Pb, Cu, Zn, Hg.

28 miles NE. Lovelock, S. P. R. R., E. flank Humboldt Range.

Triassic sediments cut by granodiorite; capped by Tertiary volcanics.

Veins and placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the

United States: U. S. Geol. Survey Bull. 624, pp. 192, 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,

pp. 218-219, 1923.

Schuette, C. N., Occurrence of quicksilver ore bodies: A. I. M. M. E. Tech.

Pub. 335, p. 40, July, 1931.

Min. Res. 1924, pt. 1, p. 445.

1925, pt. 1, p. 693.

1926, pt. 1, p. 552.

1928, pt. 1, pp. 273-274.

1929, pt. 1, p. 668.

U. S. G. S. Lovelock (adv.) topographic map.

(Santa Clara). Ag, Sb.

10 miles S. Mill City, S. P. R. R.

Triassic limestones and sandstones, with rhyolite flows.

Veins, lenses.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,

pp. 219-220, 1923.

U. S. G. S. Lovelock (adv.) topographic map.

ity (Arabia, Oreana). Ag, Pb, Sb, Au, Cu, W, Hg.

5 miles W. Oreana, S. P. R. R., on E. flank Trinity Range.

Altered granodiorite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,

pp. 220-221, 1923.

Schuette, C. N., Occurrence of quicksilver ore bodies: A. I. M. M. E. Tech.

Pub. 335, p. 40, July, 1931.

Min. Res. 1922, pt. 1, p. 335.

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1924, pt. 1, p. 445.

1925, pt. 1, p. 693.

1926, pt. 1, pp. 551-552.

1928, pt. 1, p. 472.

1929, pt. 1, p. 668.

U. S. G. S. Lovelock (adv.) topographic map.

et. Au.

10 miles W. Lovelock, S. P. R. R.

Tertiary eruptives.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada,

p. 221, 1923.

U. S. G. S. Lovelock (adv.) topographic map.

PERMITS COUNTY—Continued.

Wild Horse. Pb, Ag, As, Cu, Sb.

S. Lovelock, S. P. R. R., on E. side Humboldt Lake Range.

Triassic clates and limestones.

L. C. O. Francis Church. Mining districts and mineral resources
p. 221, 1908.

S. S. S. Lovelock and topographic map.

Wright Canyon. W.

See Francis Church. Mining districts and mineral resources.

L. C. O. Francis Church.

L. C. O. Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

S. S. S. Lovelock and topographic map.

STOCKTON COUNTY

Stockton Peak. Pb, Zn, Mn, Fe.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

L. C. O. Francis Church.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

Stockton Peak. Pb, Zn, Mn, Fe.

See Francis Church. Mining districts and mineral resources.

See Francis Church. Mining districts and mineral resources.

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See Francis Church. Mining districts and mineral resources.

WASHOE COUNTY

Wood (Round Hole). Au, Ag, Pb.

E. Sano, Susanville Branch, S. P. R. R.

Sedimentary rocks intruded by quartz monzonite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 233-234, 1923.

Min. Res. 1929, pt. 1, p. 669.

U. S. G. S. Granite topographic map.

Hole. Au.

Reynard, W. P. R. R., N. Smoke Creek Desert.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 234, 1923.

U. S. G. S. Granite Range topographic map.

elly (Gerlach). Au, Ag.

9 miles N. Gerlach, W. P. R. R.

Sedimentary rocks intruded by granodiorite and capped by Tertiary volcanics.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 234, 1923.

Min. Res. 1929, pt. 1, p. 669.

U. S. G. S. Long Valley topographic map.

o (West Comstock). Au, Ag.

W. flank Mt. Davidson in Virginia Range.

Diorite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 236, 1923.

Min. Res. 1923, pt. 1, p. 511.

1924, pt. 1, p. 448.

1925, pt. 1, p. 695.

1926, pt. 1, p. 554.

U. S. G. S. Carson topographic map.

ville. Pb, Ag, Zn, Au.

8 miles N. Gerlach, W. P. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 236-237, 1923.

Min. Res. 1922, pt. 1, p. 337.

1923, pt. 1, p. 511.

1924, pt. 1, p. 447.

1925, pt. 1, p. 695.

1926, pt. 1, p. 554.

1928, pt. 1, p. 474.

U. S. G. S. Long Valley topographic map.

ine (Reno, Crystal Peak). Au, Pl, Ag, Cu, W, Pb.

10 miles NW. Reno, S. P. R. R., V. & T. R. R., W. P. R. R.

Schists and quartz monzonite, Tertiary volcanics.

WASHOE COUNTY—Continued.

Peavine (Reno, Crystal Peak)—Continued.

Veins, replacements, placer.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 191.

Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*, pp. 237-238, 1923.

Min. Res. 1922, pt. 1, p. 237.

1923, pt. 1, p. 511.

1924, pt. 1, p. 447.

1925, pt. 1, p. 695.

1926, pt. 1, p. 554.

1928, pt. 1, p. 474.

1929, pt. 1, p. 669.

U. S. G. S. Reno topographic map.

Pyramid. Cu, Ag, Au, Pb.

32 miles N. Reno, S. P. R. R., V. & T. R. R., W. P. R. R.

Tertiary volcanics.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, p. 190, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*, p. 238, 1923.

Min. Res. 1923, pt. 1, p. 511.

1929, pt. 1, p. 669.

U. S. G. S. Reno topographic map.

Sheephead. Au.

15 miles W. Reynard, W. P. R. R.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Min. Res. 1907, pt. 1, p. 382.

U. S. G. S. Granite Range topographic map.

Steamboat Springs. Hg.

Station V. & T. R. R.

Tertiary volcanics.

Impregnations.

Lee, W. T., Stone, R. W., Gale, H. S., and others, *Guidebook of the*

United States, Part B, *The Overland Route, with a side trip to*
stone Park: U. S. Geol. Survey Bull. 612, p. 191, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, p. 192, 1917.

Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*, p. 239, 1923.

Schuette, C. N., *Occurrence of quicksilver ore bodies*: A. I. M. M.

Pub. 335, p. 45, July, 1931.

Min. Res. 1928, pt. 1, pp. 274-275.

U. S. G. S. Carson topographic map.

Washoe (Galena), Pb, Au, Ag, Zn, Cu, As.

1 mile N. Washoe, V. & T. R. R.

Granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, *Useful minerals*

United States: U. S. Geol. Survey Bull. 624, pp. 190, 194,
1917.

Lincoln, Francis Church, *Mining districts and mineral resources of Nevada*, p. 235, 1923.

WASHOE COUNTY—Continued.

hoe (Galena)—Continued.

Min. Res. 1922, pt. 1, p. 62.

1923, pt. 1, p. 511.

1924, pt. 1, pp. 447, 448.

1925, pt. 1, p. 695.

1926, pt. 1, p. 554.

1929, pt. 1, p. 669.

U. S. G. S. Carson topographic map.

ekind. Ag, Au, Pb, Zn.

4 miles NE. Reno, S. P. R. R.

Tertiary volcanics.

Veins, replacements.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 188, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 239-240, 1923.

Min. Res. 1922, pt. 1, p. 337.

1923, pt. 1, p. 511.

1924, pt. 1, p. 448.

U. S. G. S. Reno topographic map.

te Horse (Olinghouse). Au, Pl, Ag.

9 miles W. Wadsworth, S. P. R. R.

Tertiary volcanics.

Veins, contacts, placers.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 186, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

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Min. Res. 1922, pt. 1, p. 337.

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1925, pt. 1, p. 695.

1926, pt. 1, p. 554.

1928, pt. 1, p. 474.

1929, pt. 1, p. 669.

U. S. G. S. Wadsworth topographic map.

WHITE PINE COUNTY

um (Muncy Creek, Queen Springs, Ruby Hill, Schellbourne, Schell Creek, Siegel, Silver Canyon, Silver Mountain). Ag, Pb, Cu, Au, Mn.

18 to 36 miles SE. Cherry Creek; 10 miles E. Melvin, N. N. R. R.

Paleozoic sediments cut by granite porphyry and capped at northern end by Tertiary volcanics.

Contact metamorphic.

Wiel, S. C., A Nevada ore deposit (Schellbourne Range): Min. Sci. Press, vol. 88, pp. 330-331, 1904.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 241, 1923.

WHITE PINE COUNTY—Continued.

Aurum (Muncy Creek, Queen Springs, Ruby Hill, Schellbourne, Siegel, Silver Canyon, Silver Mountain)—Continued.

Min. Res. 1923, pt. 1, p. 512.

1923, pt. 1, p. 696.

1926, pt. 1, p. 554.

1928, pt. 1, p. 474.

1929, pt. 1, p. 670.

Bald Mountain. Ag, Cu, Au, Pl, W, Hg.

2.5 miles S. Elko, S. P. R. R., W. P. R. R.

Paleozoic sediments cut by quartz monzonite porphyry.

Veins, placers.

Lince's, Francis Church, Mining districts and mineral resources

pp. 241-242, 1923.

Min. Res. 1928, pt. 1, p. 277.

1929, pt. 1, p. 670.

Black Horse. Cu, Ag.

4.5 miles ENE Elko, S. P. R. R.

Paleozoic sediments cut by granite porphyry.

Veins.

Frederick, F. C., Stoddard, E. W., and Santol, Samuel. Useful mi-

neral resources of Nevada. U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lince's, Francis Church, Mining districts and mineral resources

pp. 241-242, 1923.

Min. Res. 1928, pt. 1, p. 277.

Cherry Creek (Egan Canyon, Gold Canyon). Ag, Au, Cu, Pl, W, M.

1.5 miles S. Elko, S. P. R. R., W. P. R. R. 10 miles N. Ely.

Paleozoic sediments cut by quartz monzonite porphyry.

Veins, placers, and conglomerates.

Frederick, F. C., Stoddard, E. W., and Santol, Samuel. Useful mi-

neral resources of Nevada. U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lince's, Francis Church, Mining districts and mineral resources

pp. 241-242, 1923.

Min. Res. 1928, pt. 1, p. 277.

1929, pt. 1, p. 670.

Elko, E. W. Jour. Nat. Hist. Soc. Nevada, vol. 1, p. 10, 1904.

Frederick, F. C., Stoddard, E. W., and Santol, Samuel. Useful mi-

neral resources of Nevada. U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lince's, Francis Church, Mining districts and mineral resources

pp. 241-242, 1923.

Min. Res. 1928, pt. 1, p. 277.

1929, pt. 1, p. 670.

WHITE PINE COUNTY—Continued.

le (Kern, Pleasant Valley, Regan, Tungstania). Pb, Ag, Au, Cu, W.

65 miles SE. Cherry Creek, N. N. R. R.

Sedimentary rocks cut by granite.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 195, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 245, 1923.

Min. Res. 1923, pt. 1, p. 512.

1924, pt. 1, p. 448.

1925, pt. 1, p. 696.

1926, pt. 1, p. 555.

(Robinson). Cu, Au, Ag, Pb, Zn, Mn.

Station N. N. R. R., in Egan Range.

Paleozoic sediments cut by monzonite porphyry, and capped in places by Tertiary volcanics.

Veins, contact metamorphic.

Jessup, D. W., Ore deposits of the Prince Consolidated mines (Ely mining district, Nevada): Min. Sci. Press, vol. 106, pp. 773-775, 1913.

Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western United States, Part B, The Overland Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 612, p. 160, 1915.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 192, 193, 194, 196, 197, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 245-251, 1923.

Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24, No. 2, March-April, 1929.

Min. Res. 1922, pt. 1, pp. 338-339.

1923, pt. 1, pp. 512-513.

1924, pt. 1, pp. 448-450.

1925, pt. 1, pp. 696-698.

1926, pt. 1, pp. 555-557.

1928, pt. 1, pp. 475-477.

1929, pt. 1, pp. 670-673.

U. S. G. S. Ely topographic map.

ter. Pb, Cu, Ag.

10 miles SW. Granite, N. N. R. R.

Dolomitic limestones overlying Cambrian quartzites.

Veins (?), replacements.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 251, 1923.

Min. Res. 1923, pt. 1, p. 512.

1929, pt. 1, p. 670.

Canyon. Au, Ag.

5 miles W. Cherry Creek, N. N. R. R.

Paleozoic sediments.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Min. Res. 1905, p. 273.

1906, p. 303.

1907, pt. 1, p. 382.

1908, pt. 1, p. 504.

1909, pt. 1, p. 428.

WHITE PINE COUNTY—Continued.

Granite (Steptoe). Au, Ag, Pb.

6 miles SW. Granite, N. N. R. R.

Paleozoic sediments cut by granite.

Veins, replacements.

Hill, J. M., Notes on some mining districts in eastern Nevada: U. S. Geol. Survey Bull. 648, pp. 174-180, 1916.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 194, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 251, 1923.

Min. Res. 1923, pt. 1, p. 512.

1924, pt. 1, p. 448.

1925, pt. 1, p. 696.

1926, pt. 1, p. 555.

1928, pt. 1, p. 475.

Nevada. Mn, Ag.

10 miles SE. Ely, N. N. R. R., W. slope Schell Creek Range.

Limestone.

Replacements.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 252, 1923.

Newark (Strawberry). Ag, Pb, Cu, Au.

29 miles NNE. Eureka, E. & P. R. R., E. slope Diamond Range.

Limestone.

Veins.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 198, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 252-253, 1923.

Min. Res. 1923, pt. 1, p. 338.

Osceola. Au, Pl, Ag, Pb, W.

40 miles SE. Ely, N. N. R. R.

Paleozoic sediments cut by granite porphyry.

Veins, placers.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, pp. 194, 195, 1917.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, p. 253, 1923.

Min. Res. 1923, pt. 1, p. 338.

1923, pt. 1, p. 512.

1924, pt. 1, p. 448.

1925, pt. 1, p. 696.

1926, pt. 1, p. 555.

1928, pt. 1, p. 475.

1929, pt. 1, p. 670.

Piermont. Ag, Au.

66 miles from Ely, E. slope Schell Creek Range.

Slate and quartzite.

Veins.

Lincoln, Francis Church, Mining districts and mineral resources of Nevada, pp. 253-254, 1923.

Min. Res. 1926, pt. 1, p. 555.

1928, pt. 1, p. 475.

1929, pt. 1, p. 670.

WHITE PINE COUNTY—Continued.

- ramento.** Au, Ag, W.
At Sacramento Pass, W. flank Snake Range.
Limestone and slate.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 254, 1923.
- shone (Minerva, Lexington).** W, Ag.
55 miles SE. Ely, N. N. R. R.
Limestone, veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 254-255, 1923.
- ke (Bonita).** W, Ag.
S. Baker P. O., E. flank Snake Range on Utah border.
Granite.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 255, 1923.
Min. Res. 1929, pt. 1, p. 673.
- lor (Ward).** Pb, Cu, Ag, Au.
16 miles SSE. Ely, N. N. R. R.
Paleozoic sediments cut by monzonite porphyry.
Veins, contact metamorphic.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, p. 194, 198, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 255-257.
Min. Res. 1922, pt. 1, p. 339.
1923, pt. 1, p. 514.
1924, pt. 1, p. 450.
1925, pt. 1, p. 698.
1926, pt. 1, p. 557.
1929, pt. 1, p. 477.
- gsten (Hub, Lincoln).** W. Ag.
45 miles SE. Ely, N. N. R. R., W. flank Snake Range.
Quartzites and argillites intruded by granite porphyry.
Veins.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
p. 256, 1923.
- rm Springs.** Au, Ag.
36 miles N. Ely, N. N. R. R., in Egan Range.
Quartz veins.
Min. Res. 1925, pt. 1, p. 699.
- ite Pine (Hamilton).** Pb, Ag, Cu, Au, Zn.
36 miles W. Ely, N. N. R. R.
Paleozoic sediments cut by granodiorite and monzonite.
Veins, replacements.
Lee, W. T., Stone, R. W., Gale, H. S., and others, Guidebook of the western
United States, Part B, The Overland Route, with a side trip to Yellow-
stone Park: U. S. Geol. Survey Bull. 612, p. 160, 1915.
Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the
United States: U. S. Geol. Survey Bull. 624, pp. 191, 194, 195, 1917.
Lincoln, Francis Church, Mining districts and mineral resources of Nevada,
pp. 257-259, 1923.
Ferguson, H. G., The mining districts of Nevada: Econ. Geology, vol. 24,
No. 2, March-April, 1929.

WHITE PINE COUNTY—Continued.**White Pine (Hamilton)**—Continued.

Min. Res. 1922, pt. 1, p. 339.

1923, pt. 1, p. 514.

1924, pt. 1, p. 450.

1925, pt. 1, p. 699.

1926, pt. 1, p. 557.

1928, pt. 1, p. 478.

1929, pt. 1, p. 673.

PART III—CATALOGUE OF NONMETAL OCCURRENCES BY MINERALS

The term mineral is used in its broader meaning here, including such items as slate, shale, stone, etc. Thirty-nine minerals are listed, occurring in 208 localities throughout the State. The list includes only those occurrences which have been noted or described by the United States Geological Survey, or other publications, and represents only a small part of the actual occurrences in the State.

The table on page 92 shows the distribution by counties of the nonmetal minerals listed in this bulletin.

NONMETALS BY MINERALS

ALUM

References—

- Carpenter, J. A., The mineral resources of southern Nevada: Nevada State Bureau of Mines and Mackay School of Mines, vol. 1, No. 1, November, 1929.
- Duncan, L., Recovery of potash alum and sulphur at Tonopah: Chemical and Metallurgical Engineering, vol. 24, pp. 529-530, March 23, 1921.
- Hale, H. S., and Hicks, W. B., Potash in 1917: Mineral Resources of the United States, 1917, Part 2, p. 433.
- Kewett, D. F., Deposits of magnesia alum near Fallon, Nevada: U. S. Geol. Survey Bull. 750, pp. 79-86, 1925.
- Quinn, J. E., Alum deposit near Silver Peak, Esmeralda County, Nevada: U. S. Geol. Survey Bull. 225, pp. 501-502, 1904.
- Quinn, J. E., Ore deposits of the Silver Peak quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 55, pp. 157-158, 1906.

CHURCHILL COUNTY

- on.
- 16 miles southwest of Fallon, in Secs. 16 and 17, T. 18 N., R. 26 E.
- U. S. Geol. Survey Bull. 750, pp. 79-86.
- Top. sheet Wabuska.

ELKO COUNTY

- elon.
- 14 miles north of Fenelon, on main line of Southern Pacific Railroad.
- Min. Res. 1917, pt. 2, p. 433.

ESMERALDA COUNTY

- er Peak.
- 10 miles north of Silver Peak.
- U. S. Geol. Survey Bull. 225, pp. 501-502.
- U. S. Geol. Survey Prof. Paper 55, pp. 157-158.
- Duncan, L., op. cit.
- Top. sheet Silver Peak.

CLARK COUNTY

- road Pass.
- About 9 miles beyond Railroad Pass on the road to Black Canyon, and 3 miles south.
- Carpenter, J. A., op. cit.
- Top. sheet Camp Mohave.



Alum
Shoolte
1964

ALUNITE

- nces—
ler, B. S., and Gale, H. S., Alunite—a newly discovered deposit near Marysville, Utah: U. S. Geol. Survey Bull. 511, pp. 44-48, 1912.
e, H. S., Potash salts, 1915: Mineral Resources of the United States, 1915, Part 2, pp. 111-112.
e, H. S., and Hicks, W. B., Potash in 1917: Mineral Resources of the United States, 1917, Part 2, pp. 432-433.
sorne, F. L., Geology and ore deposits of Goldfield, Nevada: U. S. Geol. Survey Prof. Paper 66, pp. 129-133, 1909.
rader, F. C., Alunite in Patagonia, Ariz., and Bovard, Nevada: Economic Geology, vol 8, pp. 752-767, 1913.
rader, F. C., Alunite at Bovard, Nevada: U. S. Geol. Survey Bull. 540, pp. 351-356, 1914.

CLARK COUNTY

- egas.
ailroad Pass, 22 miles southeast of Las Vegas.
in. Res. 1915, pt. 2, pp. 111-112.
pp. sheet Camp Mohave.

ESMERALDA COUNTY

- e.
in. Res. 1915, pt. 2, p. 112.
pp. sheet Lida.
eld.
S. Geol. Survey Bull. 511, pp. 44-48.
S. Geol. Survey Prof. Paper 66, pp. 129-133.
pp. sheet Goldfield Special.

HUMBOLDT COUNTY

- r.
miles from Sulphur and about a mile south of the Western Pacific Railroad.
in. Res. 1917, pt. 2, pp. 432-433.

MINERAL COUNTY

- l.
miles south of Rawhide and about 20 miles northeast of Thorne.
hrader, F. C., op. cit.
S. Geol. Survey Bull. 540, pp. 351-356.
pp. sheet Hawthorne.

ASPHALT

- nce—
erson, R., An occurrence of Asphaltite in northeastern Nevada: U. S. Geol. Survey Bull. 380, pp. 283-285, 1909.

EUREKA COUNTY

- miles south Palisade.

BARITE

- nces—
J. M., Barytes and strontium in 1915: Mineral Resources of the United States, 1915, Part 2, p. 176.
J. M., Barytes and barium products in 1916: Mineral Resources of the United States, 1916, Part 2, p. 250.
J. M., Barytes and barium products in 1917: Mineral Resources of the United States, 1917, Part 2, p. 288.
e, G. W., Barytes and barium products in 1918: Mineral Resources of the United States, 1918, Part 2, p. 956.
e, G. W., Barytes and barium products in 1919: Mineral Resources of the United States, 1919, Part 2, p. 340.

BRUCITE—Continued.

Tyler, P. M., Magnesium and its compounds in 1929: Mineral Resources of the United States, 1929, Part 2, p. 125.

NYE COUNTY**Downeyville.**

30 miles northeast of Luning.

Min. Res. 1927, pt. 2, p. 173.

1928, pt. 2, p. 135.

1929, pt. 2, p. 125.

Top. sheet Tonopah.

CLAY**References—**

Cox, P. E., and Moulton, D. A., A new raw material for ceramic use. American Ceramic Society, vol. 6, pp. 937-939, 1923.

Ries, Heinrich, High-grade clays of the eastern United States, with some western clays: U. S. Geol. Survey Bull. 708, pp. 124-126, 1923.

CHURCHILL COUNTY

(See Pershing County.)

LINCOLN COUNTY**Elgin.**

Near Elgin.

Locality furnished by U. S. Bureau of Mines.

Top. sheet Pioche.

MINERAL COUNTY**Sodaville (Bentonitic Clay).**

3 miles southwest of Sodaville, Sec. 12, T. 5 N., R. 34 E.

Deposit visited by G. R. Mansfield, Geological Survey.

Top. sheet Hawthorne.

NYE COUNTY**Beatty.**

9 miles east and 8 miles southeast of Beatty.

U. S. Geol. Survey Bull. 708, pp. 124-126.

Cox, P. E., op. cit.

Top. sheet Furnace Creek.

PERSHING COUNTY**Oreana.**

12 miles east of Oreana (Pitt-Rowland mine).

U. S. Geol. Survey Bull. 708, pp. 121-122.

Top. sheet Rochester mining district.

Lovelock.

25 miles east by southeast of Lovelock (near boundary between Pershing and Churchill Counties—exact location not known).

U. S. Geol. Survey Bull. 708, pp. 122-123.

Top. sheet Carson Sink.

WHITE PINE COUNTY**Ely.**

Locality furnished by U. S. Bureau of Mines.

Top. sheet Ely.

COAL**References—**

Hance, J. H., The Coaldale coal field, Esmeralda County, Nevada: U. S. Geol. Survey Bull. 531, pp. 313-322, 1913.

Spurr, J. E., Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nevada: U. S. Geol. Survey Bull. 225, pp. 289-292, 1904.

BENTONITE—Continued.

NYE COUNTY

dows.
miles northeast of Death Valley Junction.
niaga, V. M., op. cit.
is, C. W., op. cit., p. 6.
hase, John, op. cit.
sheet Furnace Creek.

MINERAL COUNTY

les southwest of Sodaville, Sec. 12, T. 5 N., R. 34 E.
osit visited by G. R. Mansfield, Geological Survey.
sheet Hawthorne.

BORATES

es—
H. S., The Callville Wash colemanite deposit: Engineering and Mining
rnal, vol. 112, No. 14, pp. 524-530, October 1, 1921.
vell, C. R., Geology of the Muddy Mountains, Nevada, with a section
ough the Virgin Range to the Grand Wash Cliffs, Ariz: U. S. Geol.
l. 798, 1928.
L. F., Colemanite in Clark County, Nevada: U. S. Geol. Survey Bull.
, pp. 23-39, 1923.
J. E., Ore deposits of the Silver Peak quadrangle, Nevada: U. S. Geol.
vey Prof. Paper 55, pp. 158-165, 1906.
: Mineral Resources of the United States, 1882, pp. 568-570.

CHURCHILL COUNTY

ings.
iles southeast of Fallon.
Res. 1882, p. 570.
sheet St. Thomas.

CLARK COUNTY

ountains.
d 34 miles northeast of Las Vegas.
Geol. Survey Bull. 735, pp. 23-39.
Geol. Survey Bull. 798.
H. S., op. cit.
sheet St. Thomas.

ESMERALDA COUNTY

e Marsh.
iles southeast of Fallon.
Geol. Survey Prof. Paper 55, pp. 158-165.
Res. 1882, pp. 568-569.
sheet Silver Peak.

Marsh.
iles southeast of Candelaria.
Res. 1882, p. 569.
sheet Tonopah.

MINERAL COUNTY

Marsh.
es south of Mina.
Res. 1882, pp. 569-570.
sheet Hawthorne.

BRUCITE

es—
M., Magnesium and its compounds in 1927: Mineral Resources of the
ted States, 1927, Part 2, p. 173.
P. M., Magnesium and its compounds in 1928: Mineral Resources of
United States, 1928, Part 2, p. 135.

an, Eugene, Brucite Deposit, Paradise Range, Nevada
Geol. Survey Bull. 735, p. 23.

DIATOMACEOUS EARTH—Continued.

NYE COUNTY

Black Spring.

Northwest of Cloverdale district, northwestern Nye County.
 Davis, C. W., op. cit.
 Top. sheet Tonopah.

PERSHING COUNTY

Velvet and Rye Patch.

East flank of Trinity Range.
 Davis, C. W., op. cit.

STOREY COUNTY

Chalk Hills (Parker and Noe).

9 miles northeast of Virginia City.
 U. S. Geol. Survey Bull. 470, p. 108.
 Min. Res. 1928, pt. 2, p. 247.
 1929, pt. 2, p. 75.
 Davis, C. W., op. cit.
 Eardley-Wilmot, V. L., op. cit.
 Top. sheet Carson.

WASHOE COUNTY

Peavine Peak.

Northwest of Reno on Peavine Peak.
 Davis, C. W., op. cit.
 Top. sheet Reno.

Verdi.

9 miles west of Reno.
 Davis, C. W., op. cit.
 Eardley-Wilmot, V. L., op. cit.
 Top. sheet Reno.

DOLOMITE

References—

- Carpenter, Jay A., The mineral resources of southern Nevada: Nevada Bureau of Mines and Mackay School of Mines Bulletin, vol. 1, November, 1929.
 Anonymous, Unusual lime operations in far west: Rock Products, 1930, pp. 41-53.

CLARK COUNTY

Sloan.

Rock products, op. cit.
 Carpenter, Jay A., op. cit.
 Top. sheet Tonopah.

DUMORTIERITE

References—

- Fairbanks, E. E., Dumortierite from Nevada: American Mineralogist, pp. 93-96, 1926.
 Jones, J. C., The geology of the deposit of dumortierite in Humboldt Canyon, Pershing County, Nevada; petrography; origin of the deposit: University of Nevada Bulletin, vol. 22, No. 2, pp. 23-26, 31, March 15, 1928.
 Knopf, Adolph, Geology and ore deposits of the Rochester district: U. S. Geol. Survey Bull. 762, 1924.

NYE COUNTY

Round Mountain.

Jones, J. C., op. cit.
 Top. sheet Tonopah.

PERSHING COUNTY

Humboldt Queen Canyon.

6 miles east of Oreana.
 Jones, J. C., op. cit.

COAL—Continued.

ESMERALDA COUNTY

le.
2 N., R. 37 E.
S. Geol. Survey Bull. 225 and 531.
p. sheet Tonopah.

DIATOMACEOUS EARTH

nces—
les, Oliver, Abrasive materials in 1928: Mineral Resources of the United States, 1928, Part 2, p. 247.
les, Oliver, Abrasive materials in 1929: Mineral Resources of the United States, 1929, Part 2, p. 75.
is, C. W., Diatomaceous earth (with special reference to Nevada): Bureau of Mines, Reports of Investigations, Serial 2718, 1925.
dley-Wilmot, V. L., Diatomite, its occurrence, preparation, and uses: Department of Mines, Mines Branch, Ottawa, Canada, 1928, pp. 104-105.
l, J. M., Notes on the economic geology of the Ramsey, Talapoosa, and White Horse mining districts, in Lyon and Washoe Counties, Nevada: U. S. Geol. Survey Bull. 470, p. 108, 1911.
onymous, First mill in Nevada to treat kieselguhr completed at Carlin, Nevada: Nevada Mining Press, pp. 13-14, September 10, 1920.

CHURCHILL COUNTY

l.
locality furnished by U. S. Bureau of Mines.
p. sheet Carson Sink.

p.
North and south of Jessup.
Davis, C. W., op. cit.
p. sheet Carson Sink.

Creek.
s miles southeast of Eastgate.
Davis, C. W., op. cit.

ELKO COUNTY

n.
1½ miles north of Vivian.
Davis, C. W., op. cit.
Eardley-Wilmot, V. L., op. cit.
Anonymous, op. cit.
Min. Res. 1928, pt. 2, p. 247.
1929, pt. 2, p. 75.

ESMERALDA COUNTY

it and Mt. Montgomery.
Min. Res. 1928, pt. 2, p. 247.
1929, pt. 2, p. 75.
White Mountain and Hawthorne topographic maps.
v Springs.
11 miles northwest of Millers.
Davis, C. W., op. cit.
Top. sheet Tonopah.
field.
Davis, C. W., op. cit.
Top. sheet Goldfield Special.

MINERAL COUNTY

alt.
Locality furnished by U. S. Bureau of Mines.
Top. sheet Hawthorne.

FULLER'S EARTH**ESMERALDA COUNTY****Basalt (nearest town).**

Locality furnished by U. S. Bureau of Mines.
Top. sheet Hawthorne or White Mountain.

NYE COUNTY**Ash Meadows.****Amargosa Valley.****Bradford Siding.****Death Valley Junction.****Johnnie.**

Localities furnished by U. S. Bureau of Mines.
Top. sheet Furnace Creek.

GRANITE AND RELATED ROCKS*References—*

- Burchard, E. F., The stone industry in the United States in 1913
Resources of the United States, 1913, Part 2, pp. 1367-1370.
Reid, John A., Preliminary report on the building stones of Nevada
University of Nevada Bull., vol. 1, No. 1, 1904.

ELKO COUNTY**Elko.**

Some distance north and south of Elko.
Reid, John A., op. cit.

HUMBOLDT COUNTY**Winnemucca.**

12 miles north of Winnemucca and on Winnemucca Peak.
Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1370.
Top. sheet Paradise.

LYON COUNTY**Mason Valley.**

In Hudson Pass.
Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1369.
Top. sheet Wellington.

MINERAL COUNTY**Luning.**

Near Luning.
Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1369.
Top. sheet Hawthorne.

ORMSBY COUNTY**Lakeview.**

South of Lakeview, 3 miles northwest of Carson City.
Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1369.
Top. sheet Carson.

STOREY COUNTY**Virginia City (Diorite).**

On Mt. Davidson.
Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1370.
Top. sheet Carson.

DUMORTIERITE—Continued.

PERSHING COUNTY—Continued.

chester.

- West slope of Lincoln Hill.
- Jones, J C., op. cit.
- Fairbanks, E. E., op. cit.
- Knopf, Adolph, op. cit.
- Top. sheet Rochester Mining District and Lovelock (adv.).

WASHOE COUNTY

anite Range.

- Southern end of Granite Range, approximately 8 miles northwest of Gerlach.
- Jones, J C., op. cit.
- Top. sheet Granite Range.

FELDSPAR

ferences—

- Carpenter, J. A., The mineral resources of southern Nevada: Nevada State Bureau of Mines and Mackay School of Mines Bulletin, vol. 1, No. 1, November, 1929.

CLARK COUNTY

pton.

- 11 miles from railroad at Nipton, Calif.
- Carpenter, J. A., op. cit.
- Top. sheet Ivanpah.

FLUORSPAR

ferences—

- Davis, H. W., Fluorspar and cryolite in 1920: Mineral Resources of the United States, 1920, Part 2, p. 72.
- Davis, H. W., Fluorspar and cryolite in 1921: Mineral Resources of the United States, 1921, Part 2, p. 42.
- Davis, H. W., Fluorspar and cryolite in 1922: Mineral Resources of the United States, 1922, Part 2, p. 18.
- Davis, H. W., Fluorspar and cryolite in 1925: Mineral Resources of the United States, 1925, Part 2, p. 11.
- Davis, H. W., Fluorspar and cryolite in 1928: Mineral Resources of the United States, 1928, Part 2, p. 23.
- Davis, H. W., Fluorspar and cryolite in 1929: Mineral Resources of the United States, 1929, Part 2, p. 13.

MINERAL COUNTY

roken Hills.

- 5½ miles from Broken Hills, Baxter mine.
- Min. Res. 1928, pt. 2, p. 23.
- 1929, pt. 2, p. 13.

It. Montgomery.

- 2¾ miles south of Mt. Montgomery Station.
- Deposit reported by Southern Pacific Company, Geological Department.
- Top. sheet White Mountain.

NYE COUNTY

Beatty.

- 4½ miles southeast of Beatty, Daisy mine, in Bare Mountains.
- Min. Res. 1920, pt. 2, p. 72.
- 1921, pt. 2, p. 42.
- 1922, pt. 2, p. 18.
- 1925, pt. 2, p. 11.
- 1928, pt. 2, p. 23.
- 1929, pt. 2, p. 13.
- Top. sheet Furnace Creek.

GYPSUM—Continued.**CLARK COUNTY—Continued.****Moapa.**

In the Muddy Range directly south of Moapa, in T. 16 S., R. 66 E.
U. S. Geol. Survey Bull. 697, p. 159.
Top. sheet St. Thomas.

Virgin River.

In the valley of Virgin River between St. Thomas and the mountain river.
U. S. Geol. Survey Bull. 697, p. 160.
Top. sheet St. Thomas.

LINCOLN COUNTY**Galt.**

In the Meadow Valley Range, 27 miles north of Moapa.
U. S. Geol. Survey Bull. 697, pp. 158-159.
Top. sheet Pioche.

LYON COUNTY**Ludwig and Mason.**

At the base of the western slope of the Smith Valley Range.
U. S. Geol. Survey Bull. 697, pp. 153-155.
Top. sheet Wellington.

MINERAL COUNTY**Hawthorne.**

3 miles west of Hawthorne.
U. S. Geol. Survey Bull. 697, p. 155.
Top. sheet Hawthorne.

ORMSBY COUNTY**Mound House.**

Near Mound House.
U. S. Geol. Survey Bull. 697, pp. 150-153.
Top. sheet Carson.

PERSHING COUNTY**Gerlach.**

At the western base of Luxor Peak toward the northern end of the Range and about 10 miles south of Gerlach.
U. S. Geol. Survey Bull. 697, p. 150.
Top. sheet Granite Range.

Lovelock.

In the west Humboldt Mountains east of Lovelock.
U. S. Geol. Survey Bull. 697, pp. 146-149.

Table Mountain.

26 miles a little south of east of Lovelock.
U. S. Geol. Survey Bull. 697, p. 150.

LIMESTONE**References—**

- Burchard, E. F., The production of lime in 1911: Mineral Resources of the United States, 1911, Part 2, p. 676.
Burchard, E. F., The stone industry in the United States in 1913: Resources of the United States, 1913, Part 2, pp. 1375, 1376.
Carpenter, Jay A., The mineral resources of southern Nevada: Nevada Bureau of Mines and Mackay School of Mines Bull., vol. 1, No. 1.
Coons, A. T., Stone in 1929: Mineral Resources of the United States, Part 2, p. 287.
Loughlin, G. F., and Coons, A. T., Lime in 1924 (p. 228), and Stone (p. 301): Mineral Resources of the United States, 1924, Part 2.
Anonymous, Unusual lime operations in far west: Rock Products, 1930, pp. 41-53.

LIMESTONE—Continued.

CLARK COUNTY

n.
Min. Res. 1913, pt. 2, p. 1376.
1924, pt. 2, pp. 228, 301.
1929, pt. 2, p. 287.
Carpenter, Jay A., op. cit.
Anonymous, Rock Products, op. cit.
Top. sheet Ivanpah.

i.
Carpenter, Jay A., op. cit.
Top. sheet Ivanpah.

EUREKA COUNTY

sade.
Locality furnished by U. S. Bureau of Mines.

LINCOLN COUNTY

e.
Locality furnished by U. S. Bureau of Mines.
Top. sheet Pioche.

LYON COUNTY

ton.
Min. Res. 1911, pt. 2, p. 676.
1913, pt. 2, p. 1375.
Top. sheet Carson.

ouska.
Min. Res. 1913, pt. 2, p. 1376.
Top. sheet Wabuska.

ORMSBY COUNTY

son City.
Min. Res. 1911, pt. 2, p. 676.
1913, pt. 2, p. 1375.
Top. sheet Carson.

MAGNESITE

erences—
Yale, H. S., Late developments of magnesite deposits in California and Nevada: U. S. Geol. Survey Bull. 540, p. 520, 1914.
Longwell, C. R., Geology of the Muddy Mountains, Nevada: U. S. Geol. Survey Bull. 798, 1928.
Yale, C. G., Magnesite in 1915: Mineral Resources of the United States, 1915, Part 2, p. 1024.
Yale, C. G., and Stone, R. W., Magnesite in 1920: Mineral Resources of the United States, 1920, Part 2, pp. 11-12.
An immense deposit of magnesite in southern Nevada: Geological Survey Press Bulletin.

CLARK COUNTY

ddy River Valley. V.
Several outcrops in the area between 2 miles west of Overton and 3 miles southwest of Kaolin.
Geological Survey Press Bulletin.
Min. Res. 1920, pt. 2, pp. 11-12.
U. S. Geol. Survey Bull. 798.
Top. sheet St. Thomas.

ESMERALDA COUNTY

dfield.
Near Goldfield.
Min. Res. 1915, pt. 2, p. 1024.
Top. sheet Goldfield Special.

MAGNESITE—Continued.**ESMERALDA COUNTY**—Continued.**Lone Mountains.**

Near Mount Diablo base line, Rs. 39 to 41 E.
U. S. Geol. Survey Bull. 540, p. 520.
Top. sheet Lida.

NYE COUNTY**Ash Meadows.**

Near Ash Meadows, T. 17 S, R. 6 E.
U. S. Geol. Survey Bull. 540, p. 520.
Top. sheet Furnace Creek.

MARBLE*References—*

Burchard, E. F., The stone industry in the United States in 1913.
Resources of the United States, 1913, Part 2, pp. 1373-1374.
Darton, N. H., Marble of White Pine County, Nevada: U. S. Geol. Survey Bull. 340, pp. 377-388, 1908.
Reid, John A., Preliminary report on the building stones of Nevada: University of Nevada Bulletin, vol. 1, No. 1, 1904.

CLARK COUNTY**Las Vegas.**

14 miles north of Las Vegas.
Min. Res. 1913, pt. 2, p. 1374.
Top. sheet Las Vegas.

ELKO COUNTY**Lamoille Valley.**

Reid, John A., op. cit.
Min. Res. 1913, pt. 2, pp. 1373-1374.

MINERAL COUNTY**Luning.**

Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1374.
Top. sheet Hawthorne.

Mina.

Near Mina.
Top. sheet Hawthorne.

NYE COUNTY**Carrara.**

9 miles south of Beatty.
Min. Res. 1913, pt. 2, p. 1374.
Top. sheet Furnace Creek.

PERSHING COUNTY**Humboldt Mountains.**

Reid, John A., op. cit.
Min. Res. 1913, pt. 2, p. 1374.

WHITE PINE COUNTY**Gandy.**

In the area between 5 and 7 miles west by south of Gandy, Utah.
U. S. Geol. Survey Bull. 340.
Min. Res. 1913, pt. 2, p. 1374.

MICA*References—*

Sterrett, D. B., Mica deposits of the United States: U. S. Geol. Survey Bull. 740, pp. 105-106, 1923.
Stoddard, B. H., Mica in 1927: Mineral Resources of the United States, 1927, Part 2, p. 189.

MICA—Continued.

CLARK COUNTY

Virgin Range.

About 15 miles east by north of Rioville, in Virgin Range.

U. S. Geol. Survey Bull. 740, pp. 105-106.

Top. sheet St. Thomas.

ELKO COUNTY

Ruby Valley.

Mutual mica mine, 6 miles south of Ruby Valley, Sec. 15, T. 29 N., R. 58 E.

Min. Res. 1927, pt. 2, p. 189.

Shoshone mica mines.

Locality furnished by U. S. Bureau of Mines.

Locality approximately 50 miles south of Elko.

Locality furnished by U. S. Bureau of Mines.

WASHOE COUNTY

Gerlach.

T. 37 N., R. 22 E., about 12 miles north of Gerlach.

U. S. Geol. Survey Bull. 523, pp. 23-25.

Top. sheet Long Valley.

NITRATE

References—

Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, pp. 19-25, 1912.

Noble, L. F., Nitrate deposits in southeastern California, with notes on southeastern Arizona and southwestern New Mexico: U. S. Geol. Survey Bull.

820 (in press, March, 1931), pp. 86-88.

CHURCHILL COUNTY

Lovelock.

On the west slope of the Humboldt Range on Humboldt Lake, southwest of Lovelock, in Churchill and Pershing Counties.

U. S. Geol. Survey Bull. 523, pp. 19-23.

Top. sheet Carson Sink.

CLARK COUNTY

Virgin Valley.

Lower valley of Muddy Creek and valley of Virgin River below St. Thomas.

U. S. Geol. Survey Bull. 820, p. 86.

Top. sheet St. Thomas.

ESMERALDA COUNTY

Fish Lake Valley.

On the east side of Fish Lake Valley.

U. S. Geol. Survey Bull. 820, p. 88.

Top. sheet Silver Peak.

HUMBOLDT COUNTY

Soldier Meadows.

Ts. 39 and 40 N., Rs. 24 and 25 E.

Unpublished manuscript.

Top. sheet Long Valley.

NYE COUNTY

Railroad Valley.

Canyons bordering west side of Railroad Valley.

U. S. Geol. Survey Bull. 523, p. 25.

PERSHING COUNTY

Lovelock. (See Churchill County.)

OIL SHALE

References—

Buwalda, J. P., Nevada in oil shale in the Rocky Mountain Region: U. S.

Geol. Survey Bull. 729, 1923, pp. 91-102.

OIL SHALE—Continued.

Alderson, V. C., The oil shale industry: New York, 1920, pp. 31-32.
 Lincoln, Francis Church, Mining districts and mineral resources
 1923.

ELKO COUNTY**Carlin.**

Near Carlin, S. P. R. R., W. P. R. R.
 Lincoln, F. C., op. cit.
 Buwalda, J. P., op. cit.

Charleston.

North of Charleston and near Copper Mountain.
 Lincoln, F. C., op. cit.

Elko.

Near Elko in western Elko County, S. P. R. R., W. P. R. R.
 Buwalda, J. P., op. cit.
 Lincoln, F. C., op. cit.
 U. S. G. S. Halleck (adv.) sheet.

NYE COUNTY**Currant.**

East of Currant in northeastern Nye County.
 Lincoln, F. C., op. cit.

WASHOE COUNTY**Peavine Mountain.**

10 miles northwest of Reno, S. P. R. R., W. P. R. R.
 Lincoln, F. C., op. cit.
 U. S. G. S. Reno top. sheet.

WHITE PINE COUNTY

At Hamilton, in White Pine Range.
 Lincoln, F. C., op. cit.

OPAL**References—**

- Bray, J. C., Opal field in Nevada: The Mining American, December 11, 1915.
 Gordon, C. C., Virgin Valley opal deposits, Nevada: Mining R Lake City, Utah, vol. 30, pp. 7-8, June 30, 1928.
 Sterrett, D. B., The production of precious stones in 1908: Minerals of the United States, 1908, Part 2, pp. 831-832.
 Sterrett, D. B., The production of gems and precious stones in 1909: Resources of the United States, 1909, Part 2, p. 771.
 Sterrett, D. B., Gems and precious stones in 1911: Mineral Resources of the United States, 1911, Part 2, p. 1060.
 Sterrett, D. B., Gems and precious stones in 1912: Mineral Resources of the United States, 1912, Part 2, pp. 1049-1050.
 Sterrett, D. B., Gems and precious stones in 1913: Mineral Resources of the United States, 1913, Part 2, pp. 677-680.

HUMBOLDT COUNTY**Virgin Valley.**

25 miles southwest of Denio, Ore.
 Min. Res. 1908, pt. 2, pp. 831-832.
 1909, pt. 2, p. 771.
 1911, pt. 2, p. 1060.
 1912, pt. 2, pp. 1049-1050.
 1913, pt. 2, pp. 677-680.

Bray, J. C., op. cit.
 Gordon, C. C., op. cit.
 Top. sheet Long Valley.

PHOSPHATE

erence—
stone, R. W., Phosphate rock in 1917: Mineral Resources of the United States, 1917, Part 2, p. 12.

CHURCHILL COUNTY

la and Huxley.
Min. Res. 1917, pt. 2, p. 12.
Top. sheet Carson Sink.

ELKO COUNTY

re.
Top of long ridge about 6 miles N. 10° E. from Cobre.
Reported occurrence.

WHITE PINE COUNTY

and Osceola.
Min. Res. 1917, pt. 2, p. 12.
Top. sheet Ely.

POTASH

erences—
ole, R. B., Exploration of salines in Silver Peak Marsh, Nevada: U. S. Geol. Survey Bull. 530, pp. 330-345, 1913.
ale, H. S., The search for potash in the desert basin region: U. S. Geol. Survey Bull. 530, pp. 295-312, 1913.
ale, H. S., Potash tests at Columbus Marsh, Nevada: U. S. Geol. Survey Bull. 540, pp. 422-427, 1914.
ale, H. S., and Hicks, W. B., Potash in 1917: Mineral Resources of the United States, 1917, Part 2, pp. 419-424.
ance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, pp. 457-469, 1914.
icks, W. B., The composition of muds from Columbus Marsh, Nevada: U. S. Geol. Survey Prof. Paper 95, pp. 1-11, 1916.
halen, W. C., Potash salts, summary for 1911: Mineral Resources of the United States, 1911, Part 2, pp. 890-891.
halen, W. C., Potash salts, summary for 1912: Mineral Resources of the United States, 1912, Part 2, pp. 880-884.
halen, W. C., Potash salts, summary for 1913: Mineral Resources of the United States, 1913, Part 2, pp. 85-86.
halen, W. C., Potash salts, 1914: Mineral Resources of the United States, 1914, Part 2, pp. 15-17.

CHURCHILL COUNTY

son Sink.
Min. Res. 1911, pt. 2, pp. 890-891.
1912, pt. 2, pp. 880-882.
U. S. Geol. Survey Bull. 530, pp. 295-312.
U. S. Geol. Survey Bull. 540, pp. 457-469.
Top. sheet Carson Sink.
e Salt Marsh (Humboldt Salt Marsh), Dixie Valley.
East of Carson Desert and Stillwater Mountains.
Min. Res. 1917, pt. 2, pp. 419-421.
U. S. Geol. Survey Bull. 540, pp. 463-464.
Top. sheet Carson Sink.
rmile Flat (Eightmile Flat and Sand Springs Valley).
15 to 30 miles southeast of Fallon.
U. S. Geol. Survey Bull. 540, pp. 462-463.
Top. sheet Carson Sink.

POTASH—Continued.**ESMERALDA COUNTY****Columbus Marsh.**

On or near the line between Esmeralda and Mineral Counties.

Min. Res. 1912, pt. 2, pp. 883-884.

1917, pt. 2, pp. 421-422.

U. S. Geol. Survey Bull. 540, pp. 422-427.

U. S. Geol. Survey Prof. Paper 95, pp. 1-11.

Top. sheets Hawthorne and Tonopah.

Fish Lake Valley.

Min. Res. 1917, pt. 2, p. 422.

Top. sheet Silver Peak.

Silver Peak Marsh.

Min. Res. 1917, pt. 2, p. 423.

U. S. Geol. Survey Bull. 530, pp. 330-345.

Top. sheet Silver Peak.

LINCOLN COUNTY**Pahranagat Lake.**

18 miles south of Pahranagat Lake.

Playa deposit examined by J. P. Buwalda. Very small amount found. Results unpublished.

Top. sheet Las Vegas.

NYE COUNTY**Ash Meadows.**

Min. Res. 1917, pt. 2, pp. 423-424.

Top. sheet Furnace Creek.

Railroad Valley.

Ts. 8 and 9 N., R. 56 E.

U. S. Geol. Survey Bull. 540, pp. 457-462.

Min. Res. 1912, pt. 2, pp. 882-883.

1913, pt. 2, pp. 85-86.

PERSHING COUNTY**Black Rock Desert.**

Northwestern Pershing County.

Min. Res. 1914, pt. 2, pp. 15-17.

Top. sheet Granite Range.

Lovelock.

7 miles north and 8 miles northeast of Lovelock.

Min. Res. 1917, pt. 2, p. 424.

WASHOE COUNTY**Smoke Creek Desert.**

4 wells drilled for potash with negative results.

Results unpublished.

Top. sheet Granite Range.

PUMICE**WASHOE COUNTY****Reno.**

5 miles west of Reno.

Locality furnished by U. S. Bureau of Mines.

Top. sheet Reno.

QUARTZ (SILICA)**CLARK COUNTY****Apex.**

1 mile southeast of Apex siding on the U. P. R. R.

Erie.

3 miles southwest of Erie siding on the U. P. R. R.

QUARTZ (SILICA)—Continued.**CLARK COUNTY**—Continued.

- Crystal.
11 miles northwest of Crystal station on the U. P. R. R.
Overton.
6 miles southwest of Overton.
White Basin.
12 miles southeast of Crystal station.

NYE COUNTY

- Atty (Riders Spur).
Locality furnished by U. S. Bureau of Mines.
Top. sheet Bullfrog Special or Furnace Creek.

SALT**References—**

- Dole, R. B., Exploration of salines in Silver Peak Marsh, Nevada: U. S. Geol. Survey Bull. 530, pp. 330-345, 1913.
Gale, H. S., Potash tests at Columbus Marsh, Nevada: U. S. Geol. Survey Bull. 540, pp. 422-427, 1914.
Hance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, pp. 457-464, 1914.
Hicks, W. B., The composition of muds from Columbus Marsh: U. S. Geol. Survey Prof. Paper 95, pp. 1-11, 1916.
Phalen, W. C., Potash salts, 1915: Mineral Resources of the United States, 1915, Part 2, pp. 108-110.
Phalen, W. C., Salt resources of the United States: U. S. Geol. Survey Bull. 669, pp. 137-148, 1919.
Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: Monograph 11, pp. 232-235, 1885.
Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 55, pp. 158-165, 1906.

CHURCHILL COUNTY**Carson Sink Salt Marsh.**

- East of Carson Desert and Stillwater Mountains.
U. S. Geol. Survey Bull. 540, pp. 463-464.
U. S. Geol. Survey Bull. 669, pp. 140-141.
Top. sheet Carson Sink.

Carson Sink (P. O. Fernley).

- 18 miles east of Wadsworth.
Mon. 11, pp. 233-234.
U. S. Geol. Survey Bull. 669, pp. 138-140.
Top. sheet Carson Sink.

Carson Sink (P. O. Hazen).

- 10 miles south of Humboldt Lake.
U. S. Geol. Survey Bull. 669, p. 140.
Top. sheet Carson Sink.

Carson Sink (P. O. Fallon).

- 25 miles southeast of Fallon.
U. S. Geol. Bull. 540, pp. 462-463.
U. S. Geol. Survey Bull. 669, pp. 137-138.
Mon. 11, pp. 234-235.
Top. sheet Carson Sink.

Carson Sink (P. O. Hazen).

- 4 miles north of Parran and 5 or 6 miles south of Humboldt Lake.
U. S. Geol. Survey Bull. 669, p. 140.
Top. sheet Carson Sink.

SALT—Continued.**CLARK COUNTY****Virgin River.**

Between St. Thomas and the mouth of Virgin River.

Min. Res. 1915, pt. 2, pp. 108-110.

U. S. Geol. Survey Bull. 669, pp. 146-148.

Top. sheet St. Thomas.

ESMERALDA COUNTY**Columbus Marsh.**

On or near the line between Esmeralda and Mineral Counties.

U. S. Geol. Survey Bull. 540, pp. 422-427.

U. S. Geol. Survey Bull. 669, p. 142.

U. S. Geol. Survey Prof. Paper 95, pp. 1-11.

Top sheet Hawthorne and Tonopah.

Silver Peak Marsh.

30 miles southeast of Columbus, in Clayton Valley, Ts. 1 and 2 S and 41 E.

U. S. Geol. Survey Prof. Paper 55, pp. 158-165.

U. S. Geol. Survey Bull. 530, pp. 330-345.

U. S. Geol. Survey Bull. 669, pp. 142-144.

Top. sheet Lida.

MINERAL COUNTY**Rhodes Marsh.**

8 miles south of Mina.

U. S. Geol. Survey Bull. 669, pp. 141-142.

Top. sheet Hawthorne.

NYE COUNTY**Railroad Valley.**

Ts. 8 and 9 N., R. 56 E.

U. S. Geol. Survey Bull. 540, pp. 457-462.

U. S. Geol. Survey Bull. 669, pp. 144-145.

WASHOE COUNTY**Smoke Creek Desert.**

Buffalo Springs Salt Works, west side of Smoke Creek Desert.

Mon. 11, pp. 232-233.

U. S. Geol. Survey Bull. 669, pp. 145-146.

Top. sheet Granite Range.

SAND AND GRAVEL**CLARK COUNTY****Overton.**

Locality furnished by U. S. Bureau of Mines.

Top. sheet St. Thomas.

WASHOE COUNTY**Reno.**

Locality furnished by U. S. Bureau of Mines.

Top. sheet Reno.

WHITE PINE COUNTY**McGill.**

Locality furnished by U. S. Bureau of Mines.

SANDSTONE**References—**

Borchard, E. F., The stone industry in the United States in 19

Resources of the United States, 1913, Part 2, pp. 1375-1376.

Reid, John A., Preliminary report on the building stones of Nevada, University of Nevada Bulletin, vol. 1, No. 1, 1904.

SANDSTONE—Continued.**CHURCHILL COUNTY****Fallon.**

Near Fallon.

Reid, John A., op. cit.

Min. Res. 1913, pt. 2, p. 1375.

Top. sheet Carson Sink.

ELKO COUNTY**Elko.**

Reid, John A., op. cit.

Min. Res. 1913, pt. 2, p. 1376.

Topographic map Halleck (adv.).

HUMBOLDT COUNTY**Winnemucca.**

Northeast of Winnemucca.

Reid, John A., op. cit.

Min. Res. 1913, pt. 2, p. 1375.

Top. sheet Paradise.

ORMSBY COUNTY**Carson City.**

Near Carson City.

Reid, John A., op. cit.

Min. Res. 1913, pt. 2, p. 1375.

Top. sheet Carson.

SLATE**References—**

Dale, T. N., and others, Slate in the United States: U. S. Geol. Survey Bull. 586, p. 87, 1914.

Dale, T. N., Note on a "black" roofing slate from Nevada: Mineral Resources of the United States, 1908, Part 2, p. 532.

HUMBOLDT COUNTY**Blue Mountains.**

21 miles northwest of Winnemucca.

U. S. Geol. Survey Bull. 586, p. 87.

Min. Res. 1908, pt. 2, p. 532.

Top. sheet Paradise or Disaster.

SODIUM SULPHATE**References—**

Chatard, T. M., Natural soda, its occurrence and utilization: U. S. Geol. Survey Bull. 60, pp. 46-53, 1890.

Melhase, John, Mining mirabilite near Wabuska, Nevada: Engineering and Mining Journal-Press, vol. 119, No. 24, pp. 965-967, June 13, 1925.

Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: Monograph 11, pp. 73-80, 1885.

Wells, R. C., Sodium sulphate, its sources and uses: U. S. Geol. Survey Bull. 717, pp. 21-24, 1923.

CHURCHILL COUNTY

Sodium carbonate chiefly; also sodium sulphate.

Sodium carbonate chiefly; also sodium sulphate.

Soda lakes two miles northeast of Leeteville.

U. S. Geol. Survey Bull. 60, pp. 46-53.

U. S. Geol. Survey Bull. 717, pp. 23-24.

Mon. 11, pp. 73-80.

Top. sheet Carson Sink.

SODIUM SULPHATE—Continued.**CLARK COUNTY****Goodsprings.**

U. S. Geol. Survey Bull. 717, p. 23.
Top. sheet Goodsprings.

ESMERALDA COUNTY**Silver Peak.**

12 miles north of Silver Peak, in southwestern part of Big Smoky
U. S. Geol. Survey Bull. 717, p. 24.
Top. sheet Silver Peak.

LYON COUNTY**Wabuska.**

East and northeast of Wabuska.
Mon. 11, p. 48,
U. S. Geol. Survey Bull. 717, p. 24.
Melhase, John, op. cit.
Top. sheet Wabuska.

MINERAL COUNTY**Rhodes Marsh.**

Near Mina.
U. S. Geol. Survey Bull. 717, p. 23.
Top. sheet Hawthorne.

Rawhide.

Near Hot Springs.
Locality furnished by U. S. Bureau of Mines.
Top. sheet Carson Sink.

PERSHING COUNTY**Brown's Station (Toy).**

U. S. Geol. Survey Bull. 717, pp. 21-22.

Buena Vista Valley.

East of Buffalo Peak in the northern part of Humboldt Range.
U. S. Geol. Survey Bull. 717, p. 22.

Sou Hot Spring (Dixie Valley).

U. S. Geol. Survey Bull. 717, p. 23.

WASHOE COUNTY**Granite Mountain.**

At the springs east of Granite Mountain, on the western border of
Creek Desert; and at the springs a few miles north of Granite
Mountain.

U. S. Geol. Survey Bull. 717, p. 23.
Top. sheet Granite Range.

Smoke Creek Desert.

U. S. Geol. Survey Bull. 717, p. 24.
Top. sheet Granite Range.

STONE (VOLCANIC ROCK)**References—**

- Burchard, E. F., The stone industry in the United States in 1911.
Resources of the United States, 1913, Part 2, pp. 1370-1373.
Reid, John A., Preliminary report on the building stones of Nevada.
University of Nevada Bulletin, vol. 1, No. 1, 1904.

LINCOLN COUNTY**Kyle (Basalt).**

Locality furnished by U. S. Bureau of Mines.
Top. sheet Pioche.

STONE (VOLCANIC ROCK)—Continued.**LYON COUNTY****Virginia City (Rhyolite).**

South of Virginia City, near the American Flat tunnel.

Min. Res. 1913, pt. 2, p. 1370.

Reid, John A., op. cit.

Top. sheet Carson.

ORMSBY COUNTY**Terminus Station (Tuff).**

Min. Res. 1913, pt. 2, pp. 1372-1373.

Reid, John A., op. cit.

Top. sheet Carson.

PERSHING COUNTY**Lovelock (Tuff).**

Northeast of Lovelock, on Southern Pacific Railroad.

Min. Res. 1913, pt. 2, p. 1373.

Reid, John A., op. cit.

Topographic map Lovelock (adv.).

STOREY COUNTY**Virginia City (Andesite).**

2 miles east of Virginia City.

Min. Res. 1913, pt. 2, p. 1372.

Reid, John A., op. cit.

Top. sheet Carson.

WASHOE COUNTY**Hulton's Quarry (Andesite).**

North of Reno.

Min. Res. 1913, pt. 2, pp. 1371-1372.

Reid, John A., op. cit.

Top. sheet Reno.

Buffakers (Andesite).

5 miles south of Reno.

Min. Res. 1913, pt. 2, p. 1371.

Reid, John A., op. cit.

Top. sheet Carson.

Reno (Andesite).

About 4 miles southwest of Reno.

Min. Res. 1913, pt. 2, p. 1371.

Reid, John A., op. cit.

Top. sheet Carson.

Reno (Andesite).

20 miles northeast of Reno.

Min. Res. 1913, pt. 2, p. 1373.

Reid, John A., op. cit.

Top. sheet Reno.

Washoe (Tuff).

Min. Res. 1913, pt. 2, p. 1373.

Reid, John A., op. cit.

Top. sheet Carson.

SULPHUR**References—**

Adams, G. I., The Rabbit Hole sulphur mines, near Humboldt House, Nevada:

U. S. Geol. Survey Bull. 225, pp. 497-500, 1903.

Becker, G. F., Geology of the quicksilver deposits of the Pacific slope:

Monograph 13, p. 346, 1888.

Crowley, A. J., A novel sulphur enterprise in Nevada: Engineering and Mining Journal-Press, vol. 118, pp. 774-776, November 15, 1924.

SULPHUR—Continued.

- Hazen, H. L., Recovering sulphur from a Nevada surface deposit: *Engineering and Mining Journal*, vol. 127, pp. 830-831, May 25, 1929.
- Ransome, F. L., The geology and ore deposits of Goldfield, Nevada: *Geol. Survey Prof. Paper* 66, pp. 109-110, 1909.
- Russell, I. C., Sulphur deposits in Utah and Nevada: *New York Academy of Sciences Transactions*, vol. 1, pp. 172-175, 1882.
- Smith, P. S., Sulphur, pyrite, and sulphuric acid in 1916: *Mineral Resources of the United States*, 1916, Part 2, pp. 410-411.
- Spurr, J. E., Alum deposit near Silver Peak, Esmeralda County, Nevada: *U. S. Geol. Survey Bull.* 225, pp. 501-502, 1904.
- Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nevada: *U. S. Geol. Survey Prof. Paper* 55, pp. 157-158, 1906.

ESMERALDA COUNTY**Cuprite.**

- Near Cuprite, 12 miles south of Goldfield.
- Min. Res. 1916, pt. 2, p. 410.
- U. S. Geol. Survey Prof. Paper 66, pp. 109-110.
- Top. sheet Lida.

Goldfield.

- A mile east of Tognoni Springs, east of Goldfield.
- Min. Res. 1916, pt. 2, p. 411.
- U. S. Geol. Survey Prof. Paper 66, p. 109.
- Top. sheet Lida.

Silver Peak.

- 10 miles north of Silver Peak.
- Min. Res. 1916, pt. 2, p. 411.
- U. S. Geol. Survey Bull. 225, pp. 501-502.
- U. S. Geol. Survey Prof. Paper 55, pp. 157-158.
- Top sheet Silver Peak.

HUMBOLDT COUNTY**Sulphur (Rabbit Hole Springs).**

- Near Sulphur and 3 miles to the east.
- U. S. Geol. Survey Bull. 225, pp. 497-500.
- Min. Res. 1916, pt. 2, p. 410.
- Crowley, A. J., *op. cit.*
- Hazen, H. L., *op. cit.*

PERSHING COUNTY**Humboldt.**

- Near Humboldt.
- Min. Res. 1916, pt. 2, p. 411.
- Russell, I. C., *op. cit.*

WASHOE COUNTY**Steamboat Springs.**

- In vicinity of Steamboat Springs between Carson City and Reno.
- Min. Res. 1916, pt. 2, p. 411.
- Mon. 13, p. 346.
- Top. sheet Carson.

TALC AND SOAPSTONE**PERSHING COUNTY****Oreana.**

- Locality furnished by U. S. Bureau of Mines.

TURQUOISE**References—**

- Sterrett, D. B., The production of gems and precious stones in 1909: *Resources of the United States*, Part 2, 1909, pp. 781-787.

TURQUOISE—Continued.

Sterrett, D. B., The production of gems and precious stones in 1910: Mineral Resources of the United States, 1910, Part 2, pp. 885-886.

Sterrett, D. B., Gems and precious stones in 1913: Mineral Resources of the United States, 1913, Part 2, pp. 697-699.

Sterrett, D. B., Gems and precious stones in 1914: Mineral Resources of the United States, 1914, Part 2, pp. 333-334.

CLARK COUNTY

sscent.

3 miles south 75° east of Crescent.

Min. Res. 1913, pt. 2, pp. 697-699.

Top. sheet Ivanpah.

ESMERALDA COUNTY

ndyke.

3 miles northeast of Klondyke.

Min. Res. 1909, pt. 2, pp. 786-787.

Top. sheet Lida.

llers.

10½ miles north 40° west and 13 miles north of west of Millers.

Min. Res. 1909, pt. 2, pp. 783-785.

Top. sheet Tonopah.

edlich.

12 miles north 40° east of Redlich; and about 1 mile southwest (two localities).

Min. Res. 1909, pt. 2, pp. 785-786.

Top. sheet Tonopah.

LANDER COUNTY

rtetz.

35 miles south of Beowawe.

Min. Res. 1914, pt. 2, pp. 333-334.

t Springs Mining District.

35 miles south of Battle Mountain.

Min. Res. 1914, pt. 2, pp. 333-334.

LYON COUNTY

rington.

7 miles north 75° west and 1½ miles north 25° west of Yerington.

Min. Res. 1910, pt. 2, pp. 885-886.

Top. sheets Wabuska and Yerington district.

NYE COUNTY

llers.

12½ miles north 12° west of Millers and 7 miles northeast of Crow Springs, and another locality about one-third mile north.

Min. Res. 1909, pt. 2, pp. 781-783.

Top. sheet Tonopah.

VARISCITE

ferences—

Sterrett, D. B., The production of gems and precious stones in 1909: Mineral Resources of the United States, 1909, Part 2, pp. 796-801.

Sterrett, D. B., The production of gems and precious stones in 1910: Mineral Resources of the United States, 1910, Part 2, pp. 890-894.

ESMERALDA COUNTY

air Junction.

9 to 11 miles east of north of Blair Junction.

Min. Res. 1910, pt. 2, pp. 892-894.

Top. sheet Tonopah.

VARISCITE—Continued.**ESMERALDA COUNTY**—Continued.**Coaldale.**

4 miles northeast of Coaldale.

Min. Res. 1910, pt. 2, pp. 890-892.

Top. sheet Tonopah.

Rock Hill Siding.

2 miles west of Rock Hill siding and $1\frac{1}{2}$ miles northwest of localities about 2 miles apart in a northeast-southwest direction.

Min. Res. 1909, pt. 2, pp. 796-801.

Top. sheets Tonopah and Hawthorne.

MINERAL COUNTY**Candelaria.**

Near the summit and on the opposite side of the mountain south of Candelaria.

Min. Res. 1910, pt. 2, p. 890.

Top. sheet Hawthorne.

Sodaville.

8 miles southwest of Sodaville.

Min. Res. 1910, pt. 2, p. 894.

Top. sheet Hawthorne.

ALPHABETIC LIST OF METAL MINING DISTRICTS

Name	County	Map No.	Page
me	Mineral	193	57
de laide	Humboldt	132	45
der	Elko	50	28
ida Valley	Esmeralda	105	39
leghany	Elko	65	31
pha	Eureka	115	42
pine	Churchill	1	17
pine	Esmeralda	90	36
unite	Clark	26	23
nador	Lander	164	51
nos	Humboldt	128	44
merican Canyon	Pershing	296	81
atelope	Eureka	116	42
atelope	Nye	216	63
atelope	Pershing	268	75
atelope Springs	Pershing	288	78
abia	Pershing	298	81
gentite	Esmeralda	91	36
rowhead	Nye	217	63
hdown	Humboldt	148	48
hens	Nye	218	63
lanta	Lincoln	167	51
wood	Nye	231	66
ra	Elko	51	28
rorra	Mineral	194	58
rum	White Pine	316	85
stin	Lander	164	51
wakening	Humboldt	128	44
ld Mountain	White Pine	317	86
nnoek	Lander	151	48
reelona	Nye	251	71
re Mountain	Nye	232	66
rrett Springs	Humboldt	150	48
rth	Eureka	127	44
salt	Mineral	196	58
ttle Mountain	Lander	151	48
atty	Nye	223	64
ll	Mineral	198	59
llehelen	Nye	219	63
ll Mountain	Churchill	2	17
lleville	Mineral	197	58
lmont	Nye	220	64
nway	Lyon	185	55
owawe	Eureka	118	42
rlin	Nye	259	73
rnice	Churchill	3	19
g Creek	Lander	152	49
g Dune	Nye	221	64

Name	County	Map No.
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Bonita	White Pine	332
Bonnie Clare	Esmeralda	112
Bovard	Mineral	195
Boyer	Churchill	21
Bristol	Lincoln	177
Broken Hills	Churchill	4
Browns	Churchill	22
Bruner	Nye	222
Buckley	Mineral	213
Buckskin	Douglas	43
Buckhorn	Eureka	117
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Bullion	Elko	82
Bullion Hill	Eureka	119
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Campbell	Lander	155
Candelaria	Mineral	197
Carlin	Elko	53
Carson River	Ormsby	265
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Castle Rock	Esmeralda	92
Cat Creek	Mineral	213
Cave Valley	Lincoln	179
Cedar	Pershing	268
Cedar Mountain	Mineral	198
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Chafey	Pershing	295
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Name	County	Map No.	Page
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Chief	Lincoln	168	51
Chinatown	Lyon	190	56
Churchill	Lyon	186	56
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Clifford	Nye	225	65
Cloverdale	Nye	226	65
Coaldale	Esmeralda	93	36
Colorado	Clark	32	24
Columbia	Elko	51	28
Columbia	Humboldt	147	47
Columbus	Mineral	197	58
Comet	Lincoln	169	52
Como	Lyon	187	56
Comstock	Storey	302	82
Concordia	Nye	237	67
Contact	Elko	55	29
Cope	Elko	79	33
Copper Basin	Lander	151	48
Copper Canyon	Lander	151	48
Copper Kettle	Churchill	6	19
Copper King	Clark	29	24
Copper Mountain	Elko	54	29
Copper Mountain	Mineral	195	58
Coppereid	Churchill	24	23
Copper Valley	Pershing	271	75
Cornucopia	Elko	56	29
Cornwall	Elko	54	29
Cortez	Eureka	119	42
Cottonwood	Washoe	304	83
Cottonwood Canyon	Churchill	21	22
Cottonwood Creek	Lander	151	48
Crescent	Clark	30	24
Crow Springs	Esmeralda	94	36
Crystal Peak	Washoe	309	83
Cuprite	Esmeralda	95	36
Currant	Nye	227	65
Danville	Nye	228	66
Dayton	Lyon	190	56
Dean	Lander	160	50
Decoy	Elko	57	29
Deep Creek	Elko	75	32
Deep Hole	Washoe	305	83
Delano	Elko	58	29
Delaware	Ormsby	266	74
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Name	County	Map No.
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Devil's Gate.....	Lyon.....	190
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Dolly.....	Esmeralda.....	97
Dolly Varden.....	Elko.....	61
Donnelly.....	Washoe.....	306
Duck Creek.....	White Pine.....	320
Dun Glen.....	Pershing.....	295
Dyer.....	Esmeralda.....	98
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Eldorado.....	Pershing.....	276
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Ellsworth.....	Nye.....	241
Ely.....	White Pine.....	322
Ely.....	Lincoln.....	180
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Eureka.....	Eureka.....	121
Fairplay.....	Nye.....	231
Fairview.....	Churchill.....	10
Falcon.....	Elko.....	83
Fallon.....	Churchill.....	12
Farrell.....	Pershing.....	273
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*Not on map.

Metal and Nonmetal Occurrences in Nevada

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Freiburg	Lincoln	172	52
Galena	Lander	151	48
Galena	Washoe	313	84
Garfield	Mineral	200	59
Gass Peak	Clark	33	25
Gardnerville	Douglas	44	27
Genoa	Douglas	45	27
Gerlach	Washoe	306	83
Geyser	Lincoln	179	54
Gilbert	Esmeralda	100	37
Gileconda	Humboldt	131	45
Gold Banks	Pershing	274	76
Gold Basin	Churchill	11	20
Gold Basin	Elko	66	31
Gold Basin	Lander	156	49
Gold Belt	Nye	229	66
Gold Butte	Clark	34	25
Gold Canyon	Lyon	190	56
Gold Canyon	White Pine	323	87
Gold Circle	Elko	67	31
Gold Crater	Nye	233	66
Gold Creek	Elko	69	31
Golden	Nye	226	65
Golden Arrow	Nye	224	67
Goldfield	Esmeralda	101	38
Gold Hill	Storey	302	82
Gold Mountain	Esmeralda	112	37
Gold Park	Lander	158	50
Gold Range	Clark	(*)	
Gold Range	Mineral	209	61
Gold Reed	Nye	240	68
Gold Run	Humboldt	132	45
Goldyke	Nye	231	66
Good Hope	Elko	68	31
Good Hope	Esmeralda	102	38
Good Springs	Clark	42	26
Gosiute Range	Elko		35
Granite	Mineral	201	60
Granite	White Pine	324	88
Granite	Elko	61	30
Grandpap	Humboldt	133	45
Grapevine	Nye	235	67
Great Eastern	Clark	29	24
Green Isle	Nye	237	67
Green Mountain	Esmeralda	111	41
Groom	Lincoln	174	53
Hamilton	White Pine	336	89
Hannapah	Nye	236	67

*Not on map.

Name	County	Map No.
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Hereules	Churchill	25
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Hiko	Lincoln	176
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Holy Cross	Churchill	12
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Hub	White Pine	334
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Hunter	White Pine	325
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Indian Springs	Lyon	187
Ione	Nye	259
Iron Hat	Pershing	278
Iron Point	Humboldt	134
Irwin Canyon	Nye	256
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Ivanhoe	Elko	70
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I. X. L.	Churchill	13
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Jarbidge	Elko	71
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Jett	Nye	238
Johnnie	Nye	239
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Juniper Range	Pershing	280
Kawich	Nye	240
Kennedy	Pershing	281
Kern	White Pine	321
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Metal and Nonmetal Occurrences in Nevada

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Bit Carson	Elko	55	29
Bondyke	Esmeralda	104	39
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Borlake	Churchill	15	21
Borlander	Lander	155	49
Borla Plata	Churchill	17	22
Borlas Vegas	Clark	36	25
Borleadville	Washoe	308	83
Borlee	Elko	74	32
Borlee	Nye	221	64
Borleete	Churchill	16	21
Borleroy	Elko	76	32
Borlewis	Lander	160	50
Borexington	White Pine	331	89
Borida	Esmeralda	105	39
Borime Mountain	Elko	75	32
Borime Point	Esmeralda	103	38
Borlincoln	White Pine	334	89
Borodi	Nye	241	68
Borogan	Clark	37	25
Borone Mountain	Elko	78	33
Borone Mountain	Esmeralda	106	39
Borone Mountain	Lincoln	178	54
Bororay	Elko	76	32
Bororing	Pershing	282	77
Borovelock	Pershing	282	77
Borucin	Elko	77	33
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Boraggie Creek	Eureka	123	43
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Boranhattan	Nye	242	68
Borarble	Nye	241	68
Borarietta	Mineral	209	61
Borason	Lyon	192	57
Borayesville	Lander	157	49
BorleCoy	Lander	161	50
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Borerrimac	Elko	78	33
Boridas	Elko	67	31
Borill Canyon	Eureka	117	42
Borill City	Pershing	283	78
Borillett	Nye	243	69
Borina	Mineral	209	61
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ot Mountain	Mineral	210	62
ne Grove	Mineral	204	60
ie Nut	Douglas	47	28
ie Nut Range	Lyon	---	56
uto	Eureka	121	42
che	Lincoln	180	54
neer	Nye	223	64
tsburgh	Lander	160	50
eerites	Pershing	287	78
asant Valley	White Pine	321	87
rtter	Elko	55	29
osi	Clark	42	26
osi	Humboldt	139	46
bble	Humboldt	139	46
inee Royal	Pershing	276	76
ector	Elko	81	33
ospect	Eureka	121	42
eblo	Humboldt	148	48
ramid	Washoe	310	84
artz Mountain	Churchill	4	19
eens	Mineral	205	60
een Springs	White Pine	316	85
bbit Hole	Humboldt	145	47
bbit Hole	Pershing	287	78
gged Top	Pershing	271	75
ilroad	Elko	82	33
ilroad Pass	Clark	26	23
ilroad Springs	Esmeralda	109	40
msey	Lyon	188	56
nd	Mineral	195	58
venswood	Lander	163	50
hwhite	Mineral	206	61
bel Creek	Humboldt	140	46
d Butte	Humboldt	141	47
d Canyon	Douglas	48	28
d Mountain	Lyon	189	56
d Mountain	Storey	303	82
d Mountain	Esmeralda	110	40
ese River	Lander	164	51
gan	White Pine	321	87
gent	Churchill	206	61
lief	Pershing	288	78
public	Nye	226	65
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ver City	Lyon	190	56
ver Glance	Douglas	49	28
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ver Horn	Lincoln	181	55
ver Lake	Douglas	48	28
ver Mountain	White Pine	316	85
ver Park	Lincoln	167	51
ver Peak	Esmeralda	110	40
ver Springs	Lincoln	.....	51
ver Star	Mineral	209	61
ver Star	Storey	302	82
ver Zone	Nye	236	67
non	Mineral	198	59
okum	Lander	165	51
an	Clark	39	26
mbering Hills	Humboldt	128	44
ith Creek	Elko	84	34
oky Valley	Lander	153	49
ake	White Pine	332	89
aville	Mineral	210	62
oma Mountains	Humboldt	144	47
thern Klondyke	Esmeralda	104	39
th Fairview	Churchill	20	22
nish Belt	Nye	251	71
encer	Lander	166	51
ing City	Humboldt	138	46
ing Valley	Eureka	121	42
ing Valley	Pershing	296	81
ruce Mountain	Elko	85	34
r	Pershing	297	81
teline	Lincoln	170	52
amboat Springs	Washoe	312	84
ptoe	White Pine	324	88
ne House	Pershing	273	76
newall Mountain	Nye	252	71
awberry	White Pine	327	88
Thomas	Clark	37	25
ecess	White Pine	320	86
livan	Ormsby	265	74
phide	Mineral	211	62
phur	Humboldt	145	47
nmit	Elko	67	31
nmit	Lander	159	50
nyside	Mineral	212	62
aset	Clark	40	26
ashine	Pershing	295	80
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Name	County	Map No.
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Warm Springs	White Pine	335
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Wedekind	Washoe	314
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ellington.....	Nye.....	262	73
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estgate.....	Churchill.....	23	22
iskey Flat.....	Mineral.....	215	63
uite Cloud.....	Churchill.....	24	23
uite Horse.....	Elko.....	89	36
uite Horse.....	Washoe.....	315	85
uite Mountains.....	Esmeralda.....	114	41
uite Pine.....	White Pine.....	336	89
uite Plains.....	Churchill.....	7	19
ld Horse.....	Pershing.....	300	82
llard.....	Pershing.....	282	77
llow Creek.....	Humboldt.....	140	46
llow Creek.....	Nye.....	263	73
llow Point.....	Humboldt.....	149	48
ndypah.....	Esmeralda.....	99	37
nnemuecca.....	Humboldt.....	150	48
lson.....	Mineral.....	204	60
lsons.....	Nye.....	264	74
onder.....	Churchill.....	25	23
orthington.....	Lincoln.....	172	52
rights Canyon.....	Pershing.....	301	82
nkee Blade.....	Lander.....	164	51
llow Pine.....	Clark.....	42	26
rington.....	Lyon.....	192	57

ALPHABETIC LIST OF NONMETALS BY MINER

Name

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 Alunite.....
 Asphalt.....
 Barite.....
 Bentonite.....
 Borates.....
 Brucite.....
 Clay.....
 Coal.....
 Diatomaceous Earth.....
 Dolomite.....
 Dunnortierite.....
 Feldspar.....
 Fluorspar.....
 Fuller's Earth.....
 Granite.....
 Graphite.....
 Gypsum.....
 Limestone.....
 Magnesite.....
 Marble.....
 Mica.....
 Nitrate.....
 Oil Shale.....
 Opal.....
 Phosphate.....
 Potash.....
 Pumice.....
 Quartz (Silica).....
 Salt.....
 Sand, Gravel.....
 Sandstone.....
 Slate.....
 Sodium Compounds.....
 Stone, Volcanic.....
 Sulphur.....
 Tale, Soapstone.....
 Turquoise.....
 Variscite.....

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UNITED STATES BUREAU OF MINES

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By

ALFRED MERRITT SMITH

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and

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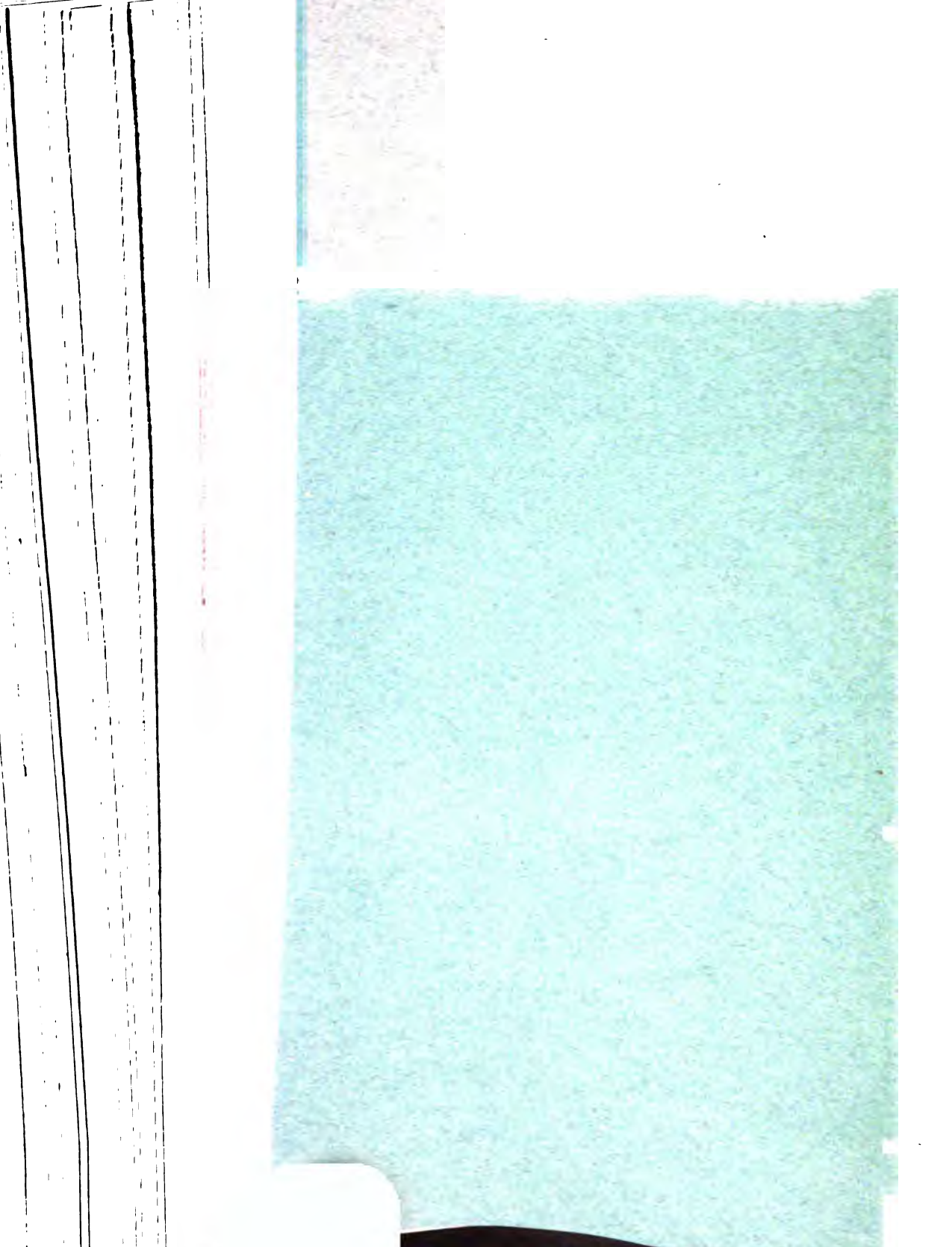
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PLACER MINING IN NEVADA

By ALFRED MERRITT SMITH¹ and WM. O. VANDERBURG²

INTRODUCTION

Placer mining has always been an attractive and often profitable branch of the mining industry. A large part of the world's gold supply has been obtained from the earth by placer mining methods. Judging from numerous inquiries received by the Nevada State Bureau of Mines, and from a general field survey of the principal placer mining districts of Nevada, there is more activity in placer mining in the State at present than there has been at any time during the last 30 years.

Gold mining is a depression-proof industry, and unlike other commodities there is always a ready market for the product no matter what the production may be. The gold mining industry is to a great extent immune to the hazards which affect other industries, as the sale of the product is unaffected by overproduction or competition, for the price is fixed at \$20.67+ per ounce. With the curtailment in the output of other metals, and the general drop in commodity prices due to adverse economic conditions, the present is an opportune time to search and mine for gold.

In addition to the several companies engaged in opening new placer workings or in reviving old ones, there are in the State a large number of prospectors and small working parties searching for placer gold wherever indications are favorable. The writers estimate that between 600 and 700 men are working in the placer areas of the State at present (1932). This does not include many itinerant individuals who have little knowledge of prospecting, yet who attempt placer mining for a few days and then quit in discouragement. The revival of placer mining will no doubt have its unfavorable features. Some of the workers who do not fully understand placer mining methods and conditions will find themselves worse off at the end than at the beginning. The general results, however, cannot fail to be beneficial and will be apparent in increased yield from the placer deposits of the State. Many miners will find employment in the placer mining districts during the present economic crisis, which will enable them at least to provide for themselves, and a few will realize

¹Mining engineer, Nevada State Bureau of Mines.

²Associate mining engineer, U. S. Bureau of Mines.

profits. Working the so-called "dry placers" by operation on a larger scale than the hand methods heretofore used will probably add materially to the placer gold production of Nevada. However, success in large scale "dry wash" must depend upon efficient operation and thorough understanding of the problems involved. In the southwest a number of costly and financially unprofitable ventures have been undertaken to recover the gold in dry placers by the use of special machinery and equipment. Prospective operators should consult all available literature on the subject before embarking on an enterprise of this nature.

In addition to the information gathered by the author in the preparation of this report, data on Nevada placers appearing in the publications of the United States Geological Survey and in the technical press have been freely used. Thanks are due to a large number of small operators who contributed data for this report. Special acknowledgment is due Louis D. Gordon, manager of the Nevada Porphyry Gold Mines, Inc., for his permission to use unpublished data on the placer operations at Roanoke, Nevada.

Thanks are especially due to Carl Stoddard, Instructor in Mining at the Mackay School of Mines, University of Nevada, for his careful reading and correcting the manuscript, and to the Nevada Bureau of Mines for the knowledge of mining in Nevada was drawn upon for this report.

SCOPE OF REPORT

The following account of placer gold occurrences in Nevada has been prepared to meet the demand for information by prospectors and others interested in the development of the placer deposits. In the past, lode mining has so overshadowed placer mining that there is a dearth of published data on the latter. This bulletin is not intended as an exhaustive final report on all the placer operations, but merely as a summary of the present status of placer gold operations. Although other deposits other than gold occur, this bulletin is confined to gold placers.

Most placer deposits in the State occur in arid or semi-arid regions where there is insufficient water available to develop the deposits by the orthodox placer mining methods. The methods for recovering gold from the dry placers, and the localities of the placer deposits, have been the subject of many inquiries by the State Bureau of Mines. The writers trust

quiries have been answered in the following pages in greater detail than could be given in letter correspondence.

BRIEF HISTORY OF PLACER MINING

The term "placer" is derived from the Spanish, and it originally signified a gravelly place in the bed or by the side of a stream where gold occurred. In the United States the word placer is applied to all surface deposits containing valuable minerals such as gold, tin, platinum, cinnabar, or tungsten, having an origin directly due to flowing water and possessing characteristics of a gravelly nature. An exception should be made of residual deposits, for streams have nothing to do with their origin.

Placer gold deposits were perhaps the first deposits of metals to be mined because they yielded gold free from base metals or gangue. References to alluvial mining date back to the dawn of civilization. Before the Christian era Egyptian inscriptions refer to the placer industry, and in the second chapter of the Bible mention is made of the "land of Havilah where gold is found."

Pliny (Caius Plinius Secundus)³ writing in the first century of the Christian era, told of gold being found in the streams in India, Spain, Italy, and other places, stated that rivers had been diverted from mountain heights, often for a hundred miles, for the purpose of washing alluvial material.

Agricola,⁴ writing about 1556 described the equipment used at that time for placer mining, which included pans, rockers, and sluices, the latter both with and without riffles. When riffles were used, the bottoms of the sluices were covered with cloth, turf, woven horsehair and the like to catch the gold. Agricola further stated that the Colchians placed the skins of animals in water to catch the gold. The legend of Jason and the Golden Fleece may have had its foundation in a piratical expedition for the purpose of looting the placer mines in Asia Minor, where fleeces were employed to catch gold in much the same manner that cocoa matting or burlap is used today.

The foregoing is sufficient to indicate that the simple equipment used in placer mining was well known to the ancients. Many of the devices employed at the present time have come down the centuries with very little improvement.

Hydraulic mining is a comparatively recent development, having been introduced into California by miners from Dahlonega,

³Agricola, Georgius. *De Re Metallica*. Translated from the first Latin edition of 1556 by Herbert Clark Hoover and Lou Henry Hoover, 1912, p. 331.

⁴Agricola, Georgius, op. cit., pp. 321-348.

Georgia, about 1850. At first, water under gravity pressure was ejected against the gravel bank through cotton hoses which were attached, similar to our present fire fighting apparatus. Subsequently iron pipe was used instead of hose, and the apparatus increased in size and changed in shape until the hydraulic monitor or monitor was evolved. With the development of the hydraulic giant, placer mining expanded rapidly, until in 1876, in Nevada alone, there were over \$100,000,000 invested in flumes, ditches and other equipment for hydraulic mining.

The use of dredges for working placer ground is the next major development in placer mining. The first successful dredge, forerunner of the present modern and efficient dredges, was operated in New Zealand in 1886. Gold dredging in Nevada States began about 1898.

PRODUCTION OF PLACER GOLD IN NEVADA

Statistics on the production of placer gold in Nevada from 1900 are incomplete. The amount of gold produced before 1900 years 1849, when placer gold was first discovered, is largely a matter of conjecture. Many of the placers were worked in the early days by Chinese, who were secretive as to their workings, and much of the gold produced by them neither reached the way to the mint nor was handled by the Wells Fargo Company.

Prior to 1900, American Canyon, in the Humboldt district, is known to have been a heavy producer, and estimates of placer gold production vary from \$10,000,000 to \$20,000,000. Barber and Wright Canyons in the Sierra districts are reported to have produced \$2,000,000. The Osceola district is known to have produced between \$2,000,000 and \$3,500,000. Those in the vicinity of Tuscarora are known to have produced about a neighborhood of \$7,000,000. Those in the vicinity of Virginia City are also known to have attained an appreciable production in the early days. Gold Canyon, below Virginia City, produced large amounts of placer gold, both before and after the discovery of the rich silver mines.

Allowing for the tendency to overestimate the production of the districts worked in the early days, and for the large production of placer districts which were worked on a small scale with little output of production, it is estimated that the total production of placer gold in Nevada from 1849 to 1900 was about \$25,000,000. Production from 1900 to 1930, as compiled from *Annual Reports on Mineral Resources of the United States* published by the United States Bureau of Mines, is shown in the following

TABLE 1

Annual Production of Placer Gold in Nevada from 1900 to 1930

Year	Fine ounces	Value	Year	Fine ounces	Value
1900	990.0	\$20,465	1916	17,139.9	\$354,313
1901	1,621.0	33,509	1917	14,153.8	292,584
1902	757.0	15,649	1918	10,564.1	218,380
1903	1,762.0	36,424	1919	6,399.4	132,288
1904	1,460.5	30,191	1920	7,383.9	152,639
1905	400.2	8,273	1921	17,567.0	363,142
1906	2,556.1	52,839	1922	11,602.4	239,842
1907	2,673.9	55,274	1923	3,941.8	81,484
1908	3,857.9	79,750	1924	1,324.0	27,369
1909	4,013.4	82,964	1925	2,536.5	52,435
1910	7,854.7	162,371	1926	2,866.2	59,249
1911	10,181.1	210,462	1927	1,809.2	37,400
1912	11,206.2	231,652	1928	1,851.1	38,266
1913	14,775.8	305,442	1929	2,117.0	43,762
1914	18,250.1	377,262	1930	1,859.4	38,437
1915	19,123.6	395,319	TOTAL	204,599.2	\$4,229,436

From 1900 to 1930 the greater part of production was from the Round Mountain, Manhattan, and Battle Mountain placers, which produced about \$1,300,000, \$800,000, and \$850,000, respectively. The placers at Rawhide are said to have yielded about \$250,000.

GENERAL GEOLOGY OF NEVADA PLACER DEPOSITS

DERIVATION OF PLACERS

Placer deposits are derived from the erosion of rocks containing gold. The gold may have existed in native form, or in association with other minerals or metals. The usual occurrence of gold is as native metal associated with quartz in veins or small seams in the country rock. Disintegration of these rocks is slowly accomplished by natural agencies, namely, the wind, rain, flowing streams, changes in temperature, chemical action, and movements of the earth's crust. These agencies working throughout geologic time reduce the rocks to gravel, sand, and clay and liberate the gold. Running water then transports the loosened rock and much of the gold away from its place of origin. Since gold has a high specific gravity it works down toward the bottom of the moving material and is concentrated on the bedrock or on impervious strata of clay known to miners as "false bedrock."

RECONCENTRATIONS

The original concentrations of gold were frequently moved again. The second movement of the gold may have been caused by a change in the gradient of the stream, due to rising or subsidence of the earth's crust, or to an increase in the flow of water at a confluence of streams which would cause increased velocity to sweep away old gravel deposits. Occasionally such secondary movement of the gold bearing gravels results in a reconcentration whereby the new deposit is made richer than the old one.

THE ACTION OF WATER

Geologic evidence shows that there was an abundance in the desert regions of Nevada at one time. This is shown by fossil shells and lacustrine deposits scattered in isolation throughout a large portion of the State. The evidence of action in the formation of gold placers is shown in some cases by the well-rounded pebbles and gold particles. The material was transported by gravity, rains, freshets and snows into the beds of ravines or streams which are now dry. The coarsest gold is usually found at the heads of these ravines or canyons, while the fine gold may have been borne from its source.

Rivers of high velocity and much water grind up the material and transport it far away from its place of origin, depositing it in curves or lessened gradient form terraces or bars. Usually the placers contain more finely divided powdery gold and are found in gulch and ravine placers.

Nearly all channels have barren as well as rich spots, the conditions prevailing at the time of the formation of the placers and the deposition of the gravel and gold. Streams are seldom rich directly opposite the mouth of a tributary stream, though both streams may contain gold, for at that point the increased volume and velocity of water will have swept the gold onward, to settle at some point where the current is retarded. Neither will much gold be found in rapids or whirlpools. Pool pits may seem ideal spots for the concentration of gold, but the gold that lodges in such holes is usually thrown out to powder by the attrition of milling gravel and sand. Repeated exploration of such places has too often resulted in disappointment.

Gold is often found in loose alluvium or wash, in which there are no rounded pebbles or rocks. This is particularly true in the desert areas of Nevada, where disintegration of the rocks produces a mass of loose material, mostly angular, and which is washed to lower land by the infrequent but heavy rains that occur in the State. Much of the finer material may be blown away by the winds during the slow process of erosion and concentration. The gold occurring in such deposits is usually angular and shows little evidence of abrasion or rounding.

In the more arid portions of Nevada, placer gold deposits may be erratic, due to cloudburst action. Rainfalls in the desert are usually short-lived but violent, and the great floods are always in the mountains where there is little soil on the slopes.

growth to retard the floods. When a cloudburst occurs, a great torrent of water, sand and gravel pours down the canyons to the lowlands. The great onrush of water destroys the slowly formed concentrations of gold by washing them on to the deltas, so that the gold in alluvial fans is usually erratic in its distribution. Coarse placer gold is often found mixed with sand and gravel in crevices in the bedrock. Placers containing fine gold in surface wash often have the gold associated with or imbedded in clay. Such gold is generally brought to the deposits by being carried in suspension in the stronger stream currents, along with sand, gravel, and clay. Sand and gravel in water become more or less mobile so that the coherence between the grains is diminished, with the result that any fine gold particles in the mass tend to slip down between the interstices of the sand and gravel and settle on more impervious clay formations beneath. Clay deposited by a stream becomes coherent and plastic and the fine gold is held by it. Clay also works under boulders in the stream beds and is there protected from the disintegrating action of the currents. Fine gold moving along over the bottom of a stream channel works its way beneath the boulders and becomes imbedded in the clay, adhering to the under side of the boulder. Very often rich gold pockets are found in clay accumulations under large boulders, close to, but not on the surface of the bedrock.

TYPES OF PLACERS

Based on their mode of origin, placers are divided into two distinct groups, namely, residual and sorted placers. These two groups are sometimes further classified according to their topographical position, such as hillside, river bar, gravel plain, bench, and others.

Residual placers are those in which the gold has accumulated in place by the disintegration of its containing rock. The gold has not been transported far from its source.

Sorted or true placers are those in which the gold has been freed from the rock containing it and transported by water to a new location. In true placers the gold generally occurs either on bedrock or on clay beds. Very often gold is found in gulches or ravines now dry or containing very little water. Some deposits are found on the tops and sides of hills where they were left by streams which changed courses or disappeared altogether as the surface of the earth changed.

Rivers often deposit gold at bends where the velocity of the transporting water is lessened, allowing the gold and gravel to

settle, thereby forming bars. As the channel cuts deeper the stream course changes, such bars are sometimes left forming bench or terrace placers, so-called because they are at a higher elevation than the present level of the stream.

RECENT PLACERS

Nearly all of the known Nevada placers have been formed by concentrations of débris carried down from the slopes of certain ranges which contain metallized areas. Many of these are "dry" placers, by which is meant that there is not now surface water that can be used to effectively mine and recover gold on the site. They are young in geologic time, and the rock fragments are rough and angular, not rounded or smoothed by the action of flowing water. The gold likewise is rough, and the particles are irregular in form.

ANCIENT PLACERS

In several localities of the State placers occur which have been formed by ancient streams of Tertiary age. No doubt that these ancient channels contain gold and are of economic importance, and a careful geologic study may lead to the discovery of ancient placers in places within the State which heretofore have escaped observation. The old river channels of the Sierra Nevada in California have contributed many millions of dollars to the world's gold supply, and they are still productive. A number of these old channels are fairly well preserved on the eastern slope of the Sierra Nevada in the Carson and Markleeville quadrangles. A particularly large and well-defined ancient stream has been described by Reid.⁵ This Tertiary river had an east-west course and has been traced from the northeast corner of Lake Tahoe to a point about four miles north of Carson City. This river is believed to have flowed eastward, although complete evidence is lacking. On the east the gravels disappear in the Virginia Range. Some of the gold found in the more recent placers of the Carson Canyon, American Flat, and Silver City areas may have been derived from this ancient river. It is said that placer gold in the early days in the above-mentioned areas differed in character, and was of higher degree of fineness than the gold derived from the Comstock Lode. The Comstock placer gold is easily recognized, as it contains much silver and has a value of only \$11 per ounce.

At Genoa, 15 miles south of Little Valley, placer gold is

⁵Reid, John A. A Tertiary River Channel near Carson City, Nevada, *U. S. Geol. and Sci. Press*, vol. 96, pp. 522-525, 1908.

in well-washed gravels believed to be of similar Tertiary origin. East of Genoa in the Mount Siegel district Tertiary placer gravels are found at a considerable elevation. Several miles farther east are the recently discovered placers of Smith Valley and Yerington, some of which are believed to be of Tertiary origin.

In the Charleston and Mountain City districts of northern Elko County are large areas of Tertiary gravel overlying rhyolite and sedimentary rocks. Concentration of these gravels by both ancient and recent streams has resulted in the formation of placers of economic importance. About 15 miles north of Jarbidge on the east fork of the Jarbidge River the deep canyon exposes successive flows of rhyolite bedded on each other. Over these rocks lie beds of clay and well-washed rounded pebbles which are capped by a recent basalt flow (Figure 1). These gravels are similar to those of Tertiary age in the Charleston and Mountain City districts.

In Walker Gulch, Rochester district, Pershing County, gravels occur which, according to Schrader,⁶ are of Tertiary age. After having been deposited by an ancient stream, the gravels were covered by several thousand feet of basalt. The basalt has now been worn away in places, exposing the gravels. In 1913 and 1914 some placer gold was found in the gravels by drift mining. Southwest of Walker Gulch in Limerick Canyon terrace gravels have been profitably mined. These gravels are of interest as they may be parts of an ancient river channel which crossed the Humboldt Range westerly through Spring Valley Pass, and the gravels, dispersed by later erosion, enriched the placers found in Spring Valley, American and South American Canyons.

RELATION OF PLACERS TO LODE MINES

Placer deposits have led to the discovery of important lodes; but in many cases the source of the placer gold has never been found. It cannot be given as a rule that placer gold originated from near-by lode deposits. Rounded or flattened particles of gold in well-washed and rounded gravel may have traveled a long distance from their source. Coarse rough gold with sharp edges, and showing more or less crystalline structure, occurring in angular unwashed gravel may indicate a near-by gold vein. Frequently, however, the source of the gold has been removed by erosion, or hidden by accumulated débris. In some cases the gold may have been concentrated from a large mass which originally contained only a very small amount of gold.

⁶Schrader, F. C. The Rochester Mining District, Nevada: U. S. Geol. Survey Bull. 580, pp. 368-370, 1913.

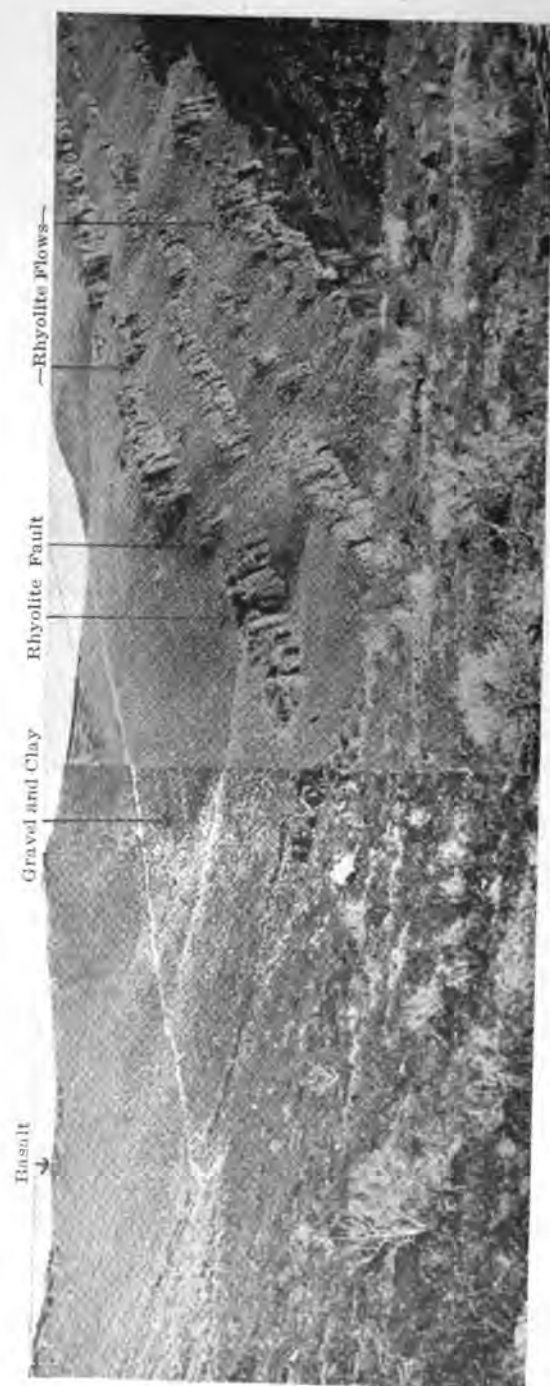


Figure 1. Tertiary gravel and clay beds north of Jarbidge, Nevada.

PROSPECTING AND SAMPLING PLACERS

The greatest incentive the placer miner has in searching for gold is the discovery of rich pockets in unsuspected places. In searching for placer deposits in new areas, it is important that the prospector bear in mind that the deposits may have little relation to the present topography, as the conditions under which some Nevada placers were formed were totally different from what they are now. It may be taken for granted that scant returns will be obtained from reworking ground that was mined by the pioneers, for as a rule these miners were very efficient with the simple equipment used. As the simpler methods have undergone little change it is unwise to rework old placer tailings unless new and better methods and equipment are available and their efficiency demonstrated. Many of the placer deposits of the State, first worked by Americans, were afterwards worked over by Chinese who were content with smaller returns.

In making a preliminary examination of a placer prospect the miner's pan is the most useful part of the prospector's equipment. In prospecting with a pan it is customary to pan samples taken from gullies or small stream courses. Due to the tendency of gold to concentrate on bedrock, an occasional test pit or shaft is necessary to expose the stratum directly above bedrock. If the results obtained by this preliminary examination are encouraging, more systematic prospecting is generally started where it has been indicated the most gold will be found, either by sinking shafts or by drilling. One should not be misled by occasional samples which run unusually high in gold, because in most of the placer deposits in the State it is possible to obtain pannings from selected parts of a deposit which show more gold than the average of the whole. In determining the average value of the gravel, the misleading effect of high pannings must be taken into account. Although pay streaks may have a very high gold content per cubic yard, it is reasonably certain that this high value will not be maintained throughout the whole auriferous area.

In small scale placer mining operations the necessity for thorough sampling prior to the installation of equipment is not so important, because in most cases the richer gravel is worked as fast as it is uncovered. However, where the indications are that the deposit must be worked on a large scale in order to be profitable, the average value per cubic yard is an all-important consideration. It is safe to say that more placer mining ventures have failed through lack of thorough sampling than for any other single reason.

Placer deposits, especially those of the dry type, can be investigated and sampled at a comparatively low cost. Gold content can be estimated with much accuracy by open cuts, pits, or by drilling. If such an investigation is properly conducted it will show very closely the quantity of gravel available, the equipment best suited to the work, and the probable percentage of gold recovery.

A novel departure from the usual methods of sinking a placer ground is employed on a placer deposit near Atlatun district, California. Special equipment for dipping pools is used and similar equipment may be used to advantage in testing placer deposits in Nevada at low cost.

The machine consists of a rotary type drill mounted on a ton automobile truck so that it is readily portable, and the drill is 28 inches in diameter. The boring apparatus is set up at the rear end of the truck and it comprises a two-part system, called a Kelly rod, to the lower end of which is attached a cylindrical bucket, in the bottom of which are two curved blades. The bucket revolves with the blades and has a latch behind each blade. As the blades revolve the gravel falls into the cylinder through the openings. The blades are made of steel and are able for sharpening or renewal, and when in operation the bucket and blade assembly revolves at a rate of 30 revolutions per minute. The Kelly rod is driven by gears at the upper end, and the weight of the drill assembly forces the blades to cut the gravel, and in hard digging extra weights can be added to the rod.

The drill and bucket is raised and lowered by a system of cable and pulley, and cable, the latter running through a block attached to the truck. When the bucket is full it is raised clear of the hole and dumped to one side. A latch releases the bottom and permits the gravel to be discharged.

The drill will readily cut soft shale and gravel, provided the boulders in the latter do not exceed the width of the opening behind the blades, which is six inches. If a boulder larger than six inches in diameter is encountered it must be removed by hand, and for this purpose a man is lowered into the hole. In some cases it is easier or safer to start a new hole. By adding lengths of rod, holes can be drilled in easy-cutting gravel to a depth of 50 feet.

Holes can be drilled in fine material or under water. The gravel is pumped through the openings in the bottom of the bucket with

lives. Two men are required to operate a single drill, although a third man is usually necessary to assist in sampling, to sharpen the blades, and to do miscellaneous work.

The drilling at Atolia was by contract with a Los Angeles company engaged in digging cesspools and sewers. The contract specified 1,000 feet of holes averaging 30 feet deep at a rate of 10 cents per foot of depth. The company expected to drill about 100 feet per day with two rigs, but owing to the presence of some large boulders the average progress was about 150 feet per day. The walls of the holes are smoother than those made by hand digging and stand well without sloughing. Each hole is 28 inches in diameter, so that each lineal foot is equivalent to 4.27 cubic feet place measurement.

No satisfactory rule can be made stating the volume of gravel necessary to produce a known gold content necessary to commercial success. It is evident that the richer the gravel the smaller need be the tonnage to insure profits. Occasionally, large deposits of very low grade gravel may be worked at very low cost and thus yield good profits. Fire assays should not be employed to determine the recoverable gold in placer ground. Panning, or the use of the rocker, gives results comparable to those obtained by placer equipment. Fire assays give results higher than those actually obtained in placer mining due to the fact that some of the gold may be enclosed in particles of quartz which are not recovered in treatment.

To determine the approximate value of mine run of auriferous gravel per cubic yard, Table 2 has been prepared as affording a simple method for the prospector. In using the table a sample of one cubic foot of loose gravel is carefully washed in a pan or rocker and the weight of the recovered gold determined. If the gold is weighed in milligrams, this weight can be converted to grains by multiplying the number of milligrams by the factor 0.03215. The fineness of the gold usually can be estimated with sufficient accuracy from previous operations in the same area. Opposite the weight of the gold in grains and under the column for fineness will be found the value of the gravel per cubic yard.

Example: A sample of one cubic foot of loose gravel yields gold weighing 1.3 grains; the gold is about 820 fine. The value per cubic yard for one grain of this fineness is \$1.114 and for .3 grain \$0.343 or a total of \$1.457 per cubic yard in place.

TABLE 2
Prospectors' Table for Determining the Approximate Value per
Auriferous Gravel

Weight of gold from 1 cu. ft. of loose gravel (Grains)	VALUE PER CUBIC YARD IN PLACE				
	FINENESS				
	720	820	860	900	960
.1.....	\$0.109	\$0.114	\$0.120	\$0.126	\$0.132
.2.....	.217	.229	.240	.251	.262
.3.....	.327	.343	.360	.377	.393
.4.....	.435	.485	.480	.502	.523
.5.....	.544	.572	.600	.628	.656
.6.....	.653	.687	.720	.753	.786
.7.....	.762	.801	.840	.879	.918
.8.....	.871	.915	.960	1.005	1.050
.9.....	.978	1.030	1.080	1.130	1.180
1.0.....	1.088	1.142	1.200	1.256	1.312
2.0.....	2.177	2.288	2.400	2.512	2.624
3.0.....	3.265	3.433	3.600	3.767	3.934
4.0.....	4.354	4.577	4.800	5.023	5.246
5.0.....	5.442	5.721	6.000	6.279	6.558

NOTE—In the above table the "swell" of the gravel is taken as 27 per cent, namely, that 27 cubic feet of gravel in place is equal to 32.4 cubic feet loose.

The pure gold content (fineness) of placer gold varies in different districts, and often in different parts of a district. The fineness usually increases with distance from the original source of the gold. Where the source has been ascertained, the placer gold is sometimes of greater average fineness than that in the veins from which it was derived.

Table 3 gives the value of gold per troy ounce at different degrees of fineness.

TABLE 3
Value of Gold per Troy Ounce at Different Degrees of Fineness
\$20.6718 per Ounce for 1,000 Fine

Fineness	Value	Fineness	Value	Fineness
600	\$12.4031	740	\$15.2972	880
610	12.6098	750	15.5039	890
620	12.8165	760	15.7106	900
630	13.0233	770	15.9173	910
640	13.2300	780	16.1240	920
650	13.4367	790	16.3307	930
660	13.6434	800	16.5375	940
670	13.8501	810	16.7442	950
680	14.0568	820	16.9509	960
690	14.2636	830	17.1536	970
700	14.4703	840	17.3643	980
710	14.6770	850	17.5711	990
720	14.8837	860	17.7778	1,000
730	15.0904	870	17.9845	

PLACER MINING METHODS AND EQUIPMENT

INTRODUCTION

Placer mining is affected by geological conditions and local environment. Climate, meteorology, topography, geology, and the ratio of volume of gravel to its gold content

have a bearing on the design, construction, and operation of placer mining equipment. The scarcity of water in Nevada, more than any factor, is the most serious drawback to successful large scale placer mining, either by dredging or hydraulicking. The question of water supply imposes a great diversity of methods in working the alluvial deposits in the State, even when worked on a small scale. Attempts have been made to work these dry placers by various methods. These include water concentration with equipment requiring a minimum amount of water, and diverse pneumatic and centrifugal appliances. Some of the machines have been used successfully when only a few yards per day are handled, and many have been failures.⁷ Very often processes and machines for placer mining are designed by those who are not familiar with the practical conditions under which the machines have to work, and in consequence many of them never get beyond the "idea" stage. The best criterion of utility in the use of a novel apparatus is in experience gained from working it under field conditions on a sufficiently large scale for a period long enough to truly demonstrate what the machine will do.

There are a number of placer deposits in Nevada, not rich enough to be profitably treated by small-scale hand methods, and too remote from sufficient water for hydraulicking or sluicing. In such instances the solving of problems will depend principally on adopting some means of treating large tonnages at low cost. The equipment for handling gravel must be very efficient, and the gravel washing machinery must require but little water, or permit the reclamation of used water.

The use of drag line excavators, scrapers, or small power shovels of the revolving type is worthy of more investigation. The application of such equipment to placer mining offers a means for cheap mining that the miner of the early days did not possess. A certain amount of prejudice exists against such equipment, due perhaps to mistakes which have been made in its use. It has sometimes been overlooked that there is a special type of machine for every job, and the equipment must be selected to fit the local conditions. No matter how successful the metallurgical treatment may be, in order to make profits the machinery used in handling the gravel must provide sufficient capacity at a low cost. Some installations in the State have been handicapped by the low capacity of the equipment. The real basis

⁷A description of 118 processes and machines for recovering placer gold is given in the April 1932 issue of *Mining in California*, published by the California Division of Mines, Ferry Building, San Francisco, to which the interested reader is referred. Price of bulletin 25 cents.

upon which to install equipment is capacity to keep at a high average efficiency.

The impression exists that placer mining requires a relatively small outlay of capital. This is true for small scale mining, but when the amount of material handled must be large, expensive equipment is necessary. Placer mining consists essentially in the excavation, transportation, screening and washing of sand and gravel, and the disposal of the tailings. When done on a large scale, expensive equipment is required. Under conditions large scale dredging or hydraulicking operations on gravel containing less than five cents in gold per cubic yard are not profitable, but such low costs cannot be approached in Nevada.

Writers on placer mining have stated that the three factors necessary for successful placer mining are sufficient gold, gravel, water in abundance, and plenty of dump room. One of these factors is seldom present in Nevada placers, yet numerous placer operations have been carried on successfully in this State.

Dry placering methods have been a means of winning gold from arid regions in Mexico, Australia and from the placers of Nevada, California, Arizona and New Mexico. One who is familiar with the operation and efficiency of the Mexican air jig, or "dry washer," it is most surprising to find such misinformation as the following in a treatise on placer mining, which has run through several editions: "it may be set down as an axiom that all of the machines will prove failures, unless the gold is so plentiful that it can be sifted from the dirt, and under the latter condition a sieve would suffice." This is incorrect. Dry placer machines are capable of treating material from which gold cannot be recovered by screening. However, this writer qualifies his conclusion by alluding to a patented pneumatic placer machine: "The writer not being particularly interested in that kind of machine has never inquired into its virtues or where it has been successfully used." The ability of the skillful dry-wash operator to make very close saving of gold has been proven countless times. An example is cited in the record of Thomas ("Dry Washer") Wilson, known throughout Nevada. Wilson won a fortune from placer gravels at Round Mountain in 1907, and is an expert in dry placering practice.

In the following pages various types of small scale placer mining equipment which have been found suitable in Nevada

other fields, are described and their limitations set forth. Additional data on placer mining equipment is also included under the various districts described in this paper.

THE PAN AND BATEA

The gold pan is a flat-bottom circular dish made of iron, copper, aluminum, or agate ware. Some gold pans have rims of smooth steel and bottoms of copper, which may be silver plated for amalgamating. The most commonly used size in Nevada has a top diameter of 16 inches and a depth of $2\frac{1}{2}$ inches with sides sloping about 40 degrees. A riffle, formed by crimping the side inward about halfway up and extending halfway around the circumference is a useful feature.

The batea is similar to the pan, but it is made of a single piece of wood, and instead of having a flat bottom is either conical or rounded, the latter type much like the old-fashioned chopping bowl used in the kitchen. In the conical shape the angle of the conical bottom is about 150 degrees. A good wood for the batea is mahogany, which should be turned with a lathe with the direction of the grain normal to the surface. The batea is especially useful in saving fine gold, which tends to adhere to the wood surface, but slides over metal. The batea is less frequently used in Nevada than the pan.

Due to its low capacity, the pan is used in Nevada mainly for sampling, prospecting, and cleaning of concentrates. Placer ground must be very rich in order to pay by panning alone, for an experienced panner can treat only about one cubic yard per day.

THE ROCKER

Rockers are in general use in the State, and they vary considerably in size and form. Some are unnecessarily elaborate, with beveled joints and flaring sides or ends, and are difficult to construct. As a rule the simpler designs are as efficient as the more elaborate ones. All rockers are constructed on the same basic lines and consist essentially of a riffled bottom, a movable screen for screening out the larger material, and a deflecting apron to direct the flow of gravel to the rear of the rocker and at the same time assist in catching the gold. In most cases the rockers are actuated by hand, although some are equipped with power. The rocking motion is necessary to concentrate the gold in the riffles, and keep the gravel moving.

Some rockers are constructed with a single apron while others have two. In addition to riffles made of wood strips, various

materials are used in rockers as gold catchers, including canvas, rubber mat, and amalgamated copper plates.

An excellent and simple type of rocker is described by Symons of the California State Division of Mines in a report of the California State Mineralogist (Figures 1 and 2). The dimension of parts is tabulated as follows:

- A—End, one piece 1" x 14", 16" long.
- B—Sides, two pieces 1" x 14", 48" long.
- C—Bottom, one piece 1" x 14", 44" long.
- D—Middle spreader, one piece 1" x 6", 16" long.
- E—End spreader, one piece 1" x 4", 15" long.
- F—Rockers, two pieces 2" x 5", 17" long.
- H—Screen, about 16" square outside dimensions with screen. Four pieces of 1" x 4", 15½" long and one piece 16" square with ¼" or ½" openings or sheet metal with similar size round openings.
- K—Apron, made of 1" x 2" stubs covered loosely with canvas, cleats and apron, etc., 27 feet of 1" x 2" is needed. Pieces of ⅜" iron rod 19" threaded 2" on each end, fitted with nuts and washers.
- L—The handle, in Mr. Symon's drawing, is fitted on the screen. It helps to lift the screen from the body. Sometimes it is fastened to the body.

In the center of each rocker is a spike which fits into a hole bored into the planks on which the rocker stands, to prevent rocking. Riffles should be made so they may be easily removed for cleaning up. A dipper made of a tomato can with a 30-inch handle and bottom is also necessary for adding water.

The rocker is not as efficient as the pan in saving water because of its larger capacity the total recovery is much less. The capacity of a rocker varies with its size, the character of the material treated, and the experience of the operator, and it may range from 2½ to 5 cubic yards per man shift. The water required may range from 75 to 250 gallons per day, depending on whether the water is reclaimed and the amount of clay in the material.

Where the water supply is small, or where water must be hauled some distance, it is advantageous to use a tight box in which the water can be reclaimed. The box is made of lumber, about 6 feet long, 4 feet wide and 1 foot deep. The dipper can be placed directly in the box, and the tailings and water from the rocker allowed to run into it. The tailings should be removed out as seldom as possible to avoid sliming the water.

In operating the rocker, the gravel is shoveled into the box and water poured in at the same time the rocker is moved. The most effective movement of the rocker is not a slow back and fro" movement but a quick jerk and sudden stop.

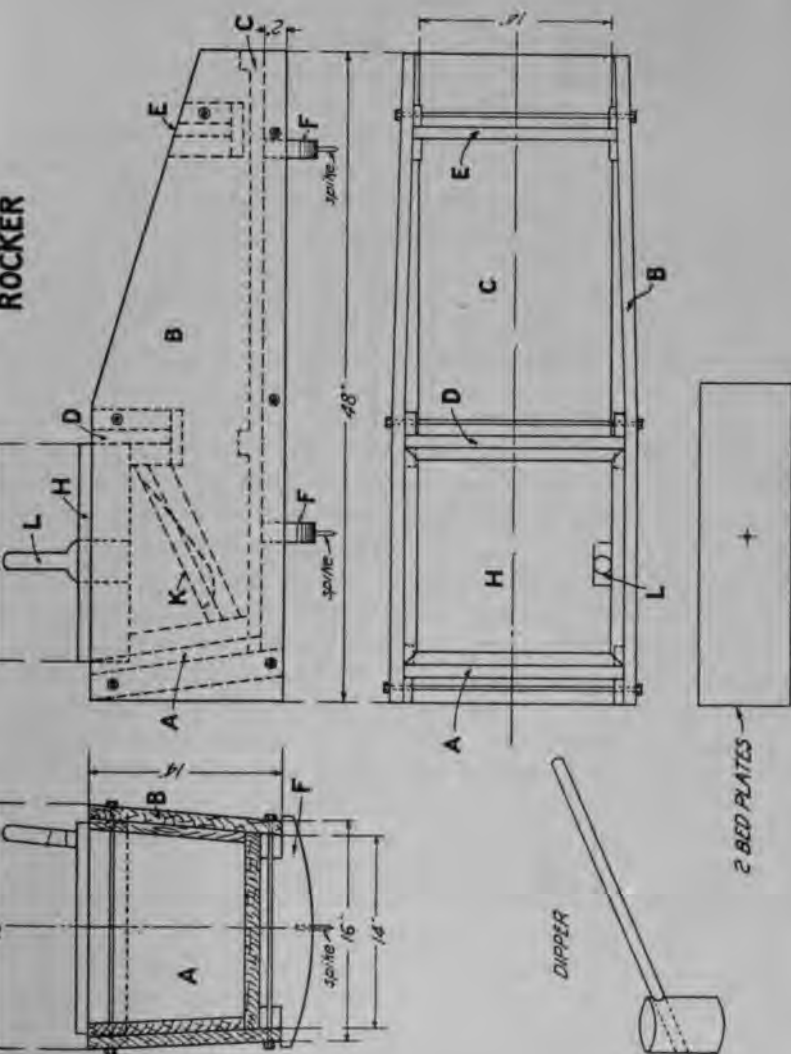
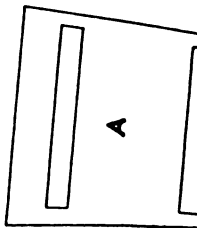
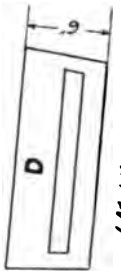
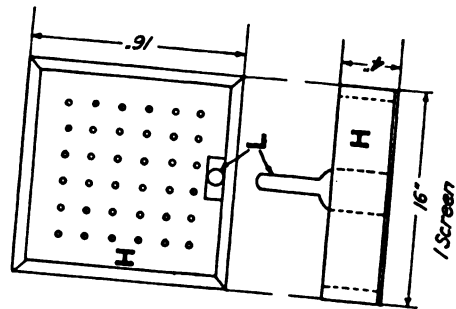
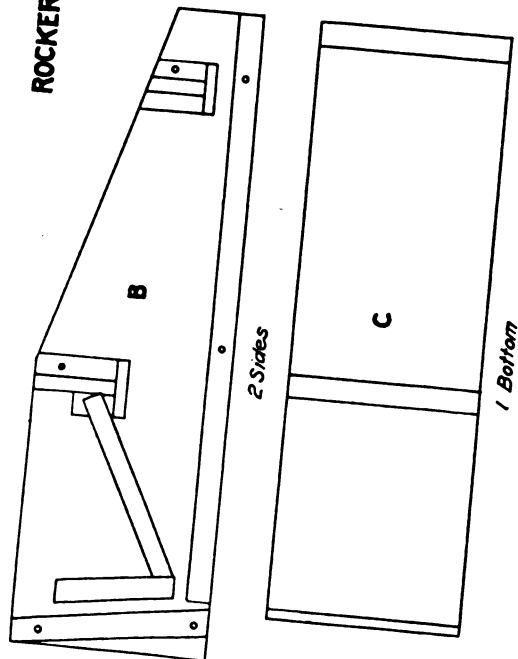


Figure 2. Rocker assembled.

ROCKER PARTS



gold is present, care must be exercised in the amount of water used, because by using too much the fine particles of gold may be washed over the riffles. Black sand should not be allowed to build up to the top of the riffles, but should be removed and at the same time the apron washed off into a tub. To assist in the recovery of fine gold, the lower part of the rocker may consist of an amalgamation plate on which mercury has been rubbed, and the canvas apron may be replaced by a piece of blanket or other material which has a nap on it.

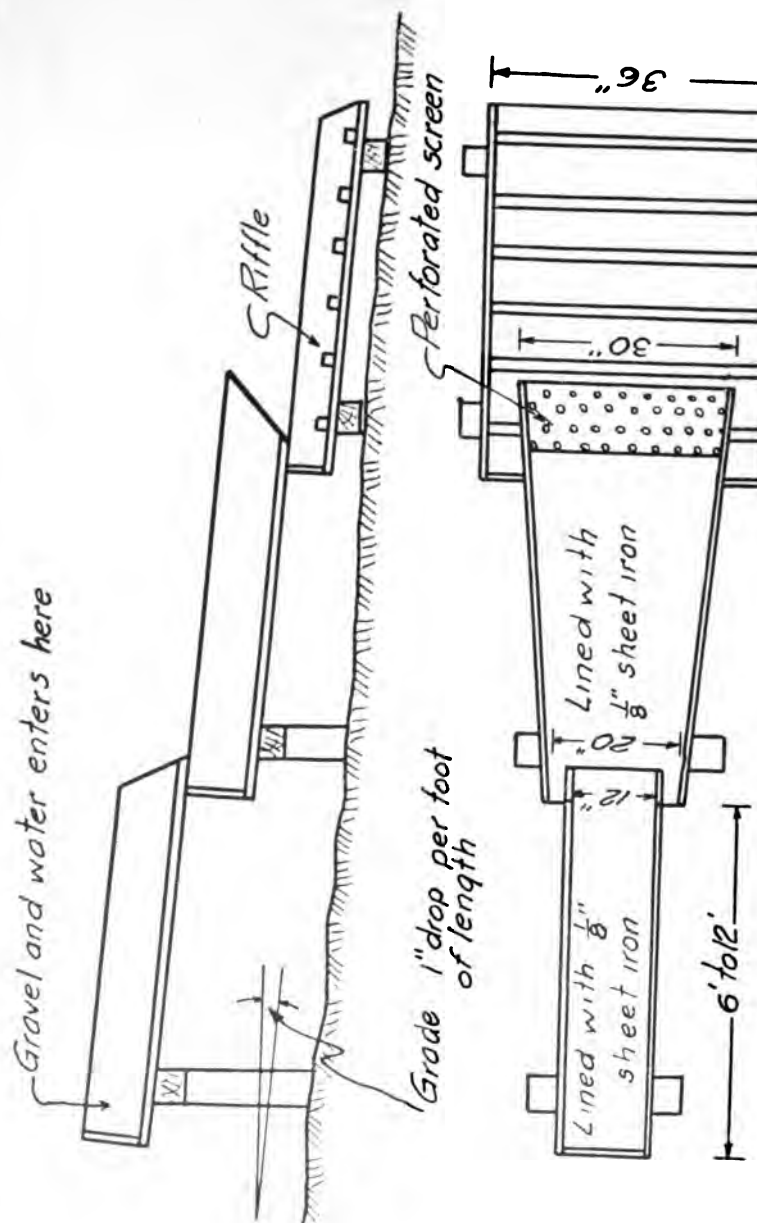
Where the auriferous gravel is loosely cemented or contains considerable clay, it is advisable to use a puddling tub in order to thoroughly disintegrate the material before treating it in the rocker. This practice saves time and makes the working of the rocker much easier. A puddling tub can be made of the bottom half of a large wooden barrel. The gravel is disintegrated by mixing it with water in the tub and stirring it with a rake. A plug several inches above the bottom is convenient for drawing off the clay held in suspension before the gravel is shoveled into the rocker.

THE LONG TOM

There are several forms of the long tom. The usual one is an inclined trough or modified sluice box. The long tom requires more water than the rocker and, although of larger capacity than the rocker, it is not so efficient.

A sketch of a long tom is shown in Figure 4. The long tom is ordinarily built in three sections. The upper section is a sluice box 6 to 12 feet long, 8 to 10 inches deep, and 12 inches wide, the bottom of which is lined with sheet iron. The middle section is 6 to 12 feet long, about 20 inches wide at the upper end and increasing to 30 inches at the lower. This section is also lined on the bottom with sheet iron. The bottom of the widest portion consists of a strong perforated sheet iron screen or tom iron which is inclined at an angle of 45 degrees. The lower section, or riffle box, is 6 to 12 feet long by 36 inches wide. Riffles and canvas are placed in the bottom of this section to catch the gold. The grade of all three sections is about 1 inch per foot.

The long tom is placed in position as near the ground as possible and the water allowed to enter at the upper end, either through a hose or trough. Two or more men shovel the gravel into the upper end and the water carries it downward to the middle section where a third man stirs the gravel about on the tom iron until all except the larger stones has passed through. These are forked out and thrown aside. The smaller particles of gravel and gold pass through the tom iron and into the riffle box where the



is held by the riffles, while the gravel passes out the lower end. The long tom is not recommended where only a small amount of water is available. A disadvantage of the long tom is that the riffle box is too short and some of the finer gold particles do not have time to settle.

A form of long tom used in Nevada is simply a sluice box 12 or 15 feet long mounted on springs so that it may be rocked by a small gasoline engine. At the feed end a perforated plate about 6 feet long is fastened above a small riffle box. In the lower portion of the box are the usual sluice-box riffles. The short upper



Figure 5. Power driven long tom used at Lynn, Nevada.

portion of riffles is cleaned out frequently to prevent loss of gold (figure 5).

THE SLUICE

Of all the small scale methods of placer mining, the sluice is probably the most effective device for separating gold from gravel with the least amount of energy. The sluice is widely used in Nevada, particularly during the spring season when there is more water than at any other time of the year. The sluice consists generally of a wooden launder equipped with riffles through which the gravel is transported by running water. A sluice may also be a ditch cut in bedrock, and is then named a ground sluice. When constructed of wood the size of a sluice depends on a number of factors, among which are the following:

1. The character of the gold, fine or coarse.
2. The physical properties of the gravel; fine, coarse, smooth or angular, or clayey.

3. The quantity of gravel.
4. The quantity of water available.
5. The gradient and dump room.

For hand shoveling operations a wood sluice is ordinarily 8 to 12 inches deep, and several "boxes" in length. In the west a sluice "box" is generally 12 feet long. Boxes may be constructed as a continuous flume of various lengths. In the latter case, one end of the box is made wider than the other so that the narrow end telescopes into the end of the one below. This sectional construction makes it easier when it is necessary to move a number of boxes to a different locality.

The grade of the sluice varies from 4 to 8 inches per foot. If carefully constructed, the swelling of the lumber will usually be sufficient to make the bottom of the sluice tight so that no gold can escape.

The bottom of the sluice is covered with riffles which may be constructed of different materials. Various types of riffles are made for the small sluice. Angle iron, plank with two or three tapered auger holes, woven wire screen, transverse wooden blocks, either wood or metal, wooden blocks placed endwise, iron rails placed longitudinally in the bottom of the sluice, may be used alone or in combinations. The relative advantage of one type of riffle is largely a matter of individual opinion; in general, the selection of the riffle is decided by the material available.

Riffles should not be permanently fastened in the sluice so that it is necessary to remove them for the clean-up. Transverse riffles may be constructed in sections, and held in place either by their own weight when of iron, or by wedges when of wood.

At the lower end of the sluice, the finer material is screened out and run over a blanket, cocoa matting, or other material which is adaptable to the recovery of fine gold.

In operating the sluice, the gravel is shoveled into the sluice, larger boulders removed, either by hand or with a fork. In some cases the oversize material is removed by shoveling it over the side on to a grizzly at the head of the sluice. In some cases mercury is placed behind the riffles to catch the fine gold. After clean-up is made by removing the riffles and allowing a strong stream of water to flow down the sluice to wash the material. The nuggets are picked up by hand and the black sand and waste material collected and washed in a gold pan or rocker. The sands, if magnetic, may be separated from the gold by using a magnet.

er drying the concentrate. To prevent fouling of the magnet piece of cellophane may be interposed between the magnet and the magnetic material.

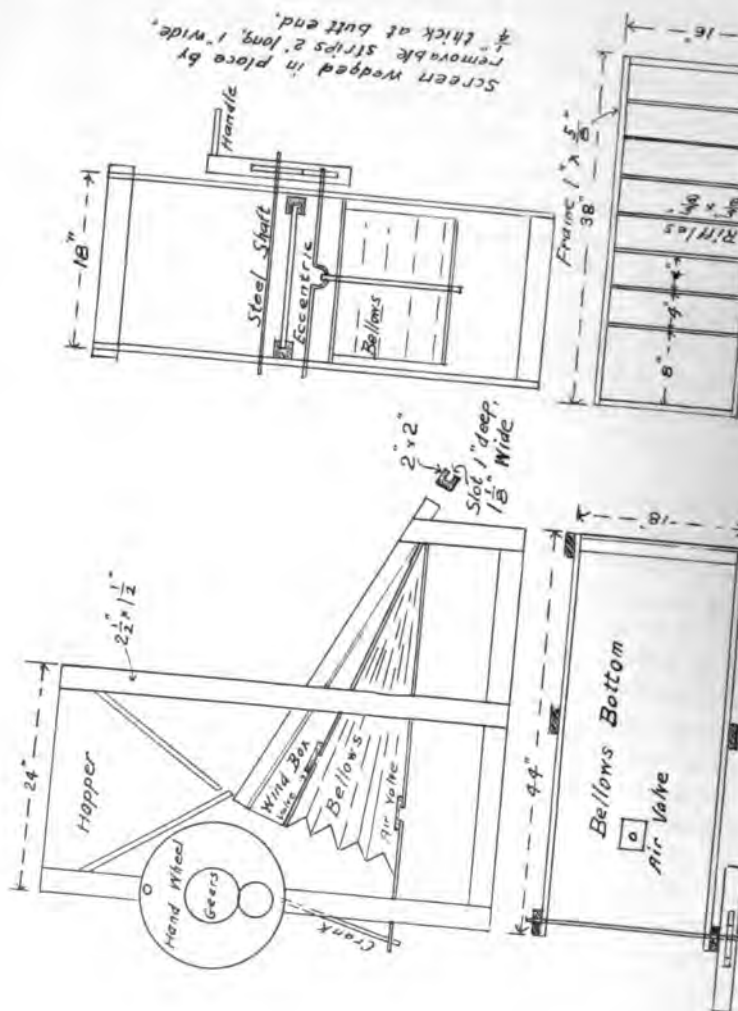
RETORTING

If mercury is used, the amalgam is collected and softened with an excess of mercury so that the valueless material may be skimmed off the surface. The excess mercury is removed by squeezing through a chamois skin. The amalgam is then retorted and the quicksilver recovered. When there is only a small quantity of amalgam, the quicksilver may be driven off by heating the amalgam on a shovel over a fire. Care must be exercised when the amalgam is reduced in this manner as mercury fumes are very poisonous.

A simple method used by placer miners to retort a very small amount of amalgam is to place it on a shovel or iron plate and cover it with half of a raw potato in which a hole has been popped out. After heating in a fire to distill off the mercury, the dead sponge is found on the iron, and a portion of the mercury may be recovered by breaking up the potato and panning the pulp.

THE DRY WASHER

Dry washing machines or dry concentrators of various designs and sizes are used in working placer deposits where insufficient water is available for wet methods. Despite the large number of dry washing machines that have appeared from time to time, the one that is in most general use is the Mexican dry washer. This machine has proved satisfactory for small placer mining operations, and it is simple to construct. Although there are a number of different styles of dry washer, they are all patterned on the same principle and one general description fits them. The dry washer operates on a principle similar to the jig. It consists essentially of a screen, a hopper, riffle board, and bellows, all mounted on a wooden framework. A drawing of a dry washer, kindly furnished by Mr. Ben Hood of Reno, is shown in Figure 6. The bellows at the bottom of the frame is made of canvas. The canvas bellows has a life of about 150 yards of placer material. The top of the bellows forms the riffle board and consists of a light detachable frame. The frame is covered with wire netting over which is stretched either canvas or linen cloth. Attached to the riffle board are transverse riffles spaced from 4 to 6 inches apart. Figure 7 shows a home-made dry washer machine in use in the Ceola district. The cost of constructing a dry washer, including labor and materials, varies from \$25 to \$40. The capacity



a single machine depends on the character of the gravel, its physical condition, and the manner in which it is prepared for treatment. The quantity will vary from $1\frac{1}{2}$ to 4 cubic yards per man per day.

The bellows, which forces intermittent gusts of air through the riffle board, is actuated by hand crank and eccentric. Usually the gear ratio is such that one revolution of the crank works the bellows three times.

A design of a type of dry placer blower used in Australia is shown in Figure 8. A is a shaking screen of punched sheet iron through which a reciprocal shaking movement may be imparted by hand. Undersize passes through to metal chutes, B, and oversize is discharged over the edge. The chutes, B, deliver to a



Figure 7. Recovering gold by dry washer in the Osceola District.

removable tray, C, provided with riffles and a bottom of coarse cloth or toweling backed by metal screen. This tray may be 10 or 12 inches long and 6 inches wide, or larger, and sits in the top of a wind box, D, having clack valves in the bottom, through which air from the 18- or 20-inch bellows, E, enters. The wind box sits on the bellows. The latter is operated from screen A, through a system of levers F. Screen A and bellows are set in a steel frame at suitable angles. In Figure 8 the motion is longitudinal, but in other designs it may be sideways. When properly designed this machine is said to be capable of recovering fine gold. Still another type is the Hungarian dry washer, simple in design, belt driven either by hand or power, shown in Figure 9. It has been in use in Europe more than a century. A machine of

average size worked by two men is said to have a 15 to 20 tons per day. La Ciénega, Sonora, Mexico, was of intensive operations by the Serna family from 18 who employed 10,000 laborers to work the rich g Hungarian dry washers.

Either one or two men operate a machine, two being satisfactory, because one man can turn the crank which shovels the alluvium on to the screen. The intermittent blow the light particles of sand and dust away, while the material works down the riffle board and discharges at the end. The gold and black sands are caught by the riffles.

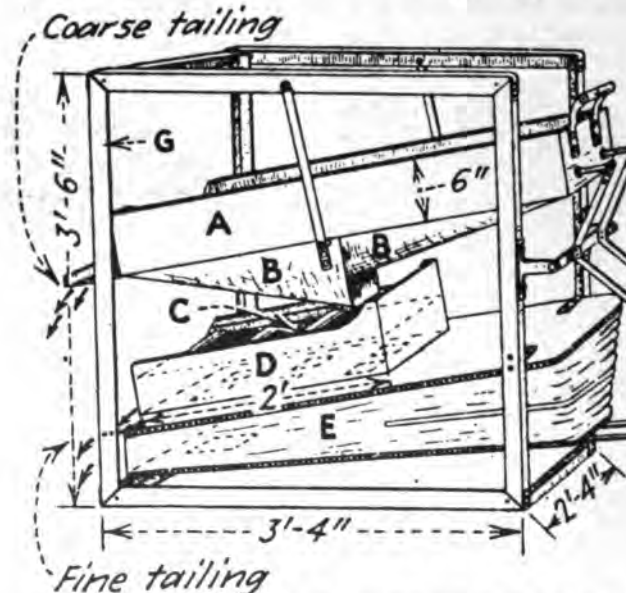


Figure 8. Type of dry blower common in Australia.
(Courtesy E. P. M. J.)

two or three wheelbarrowfuls of gravel have been run through the machine, the riffle board is taken out and the concentrate is dumped on a sheet of canvas. This concentrate is cleaned by rerunning through the machine when a sufficient amount is collected, or by panning. If the gold is not too fine, a 90 per cent recovery can be made.

Some skill is required to successfully operate a dry blower. To make a satisfactory saving, the material put through the machine must be thoroughly dry and disintegrated. Any clay present must be pulverized.

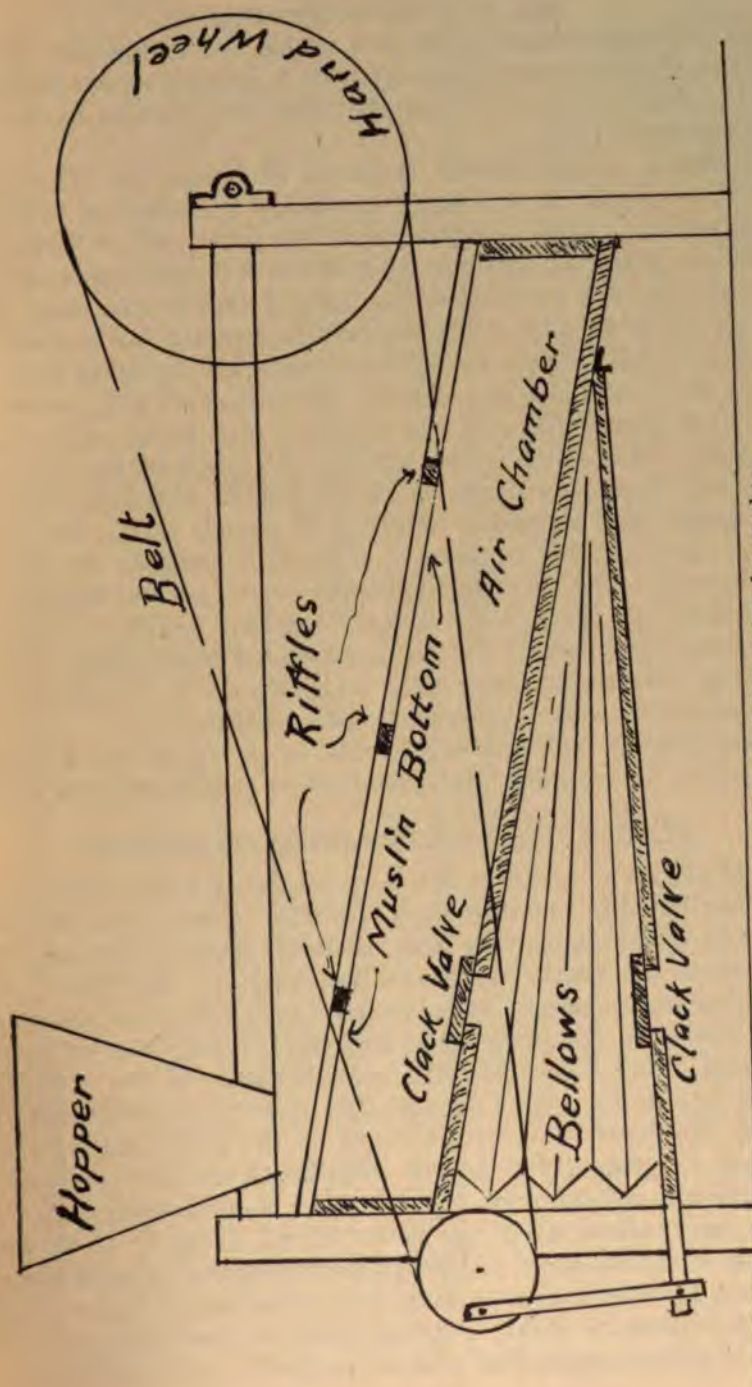


Figure 9. Sketch of Hungarian dry washer.

THE QUENNER DISINTEGRATOR

The Quenner disintegrator is a simple and inexpensive for breaking up cemented gravel prior to sluicing or dredging. It was first used in working the Altar dry placers in Mexico, about 1910.

A sketch of the machine is shown in Figure 10. The disintegrator consists of a trommel screen and a number of hammers mounted on a shaft independent of the trommel. The machine is capable of handling from 250 to 300 cubic yards of material. It is made up of a trommel 6 feet long, 3 feet in diameter, with 2-inch diameter holes. The trommel is mounted horizontally on two flanged wheels, and is revolved by chain and sprocket. It makes about 25 revolutions per minute. A steel shaft 3 inches in diameter passes through the trommel and turns on two roller bearings. Journals. This shaft is belt driven. Attached to the shaft by bolts and clamps are 12 chains, on the ends of which are manganese steel hammers weighing 16 pounds each. The shaft turns counter to the trommel at a speed of about 500 revolutions per minute. The revolving hammers and trommel break up the gravel and carry it through the machine rapidly. The centrifugal force holds the chains to a rigid position. When running, they do not break when a boulder too hard to crush is encountered as would be the case with rigid rods.

The trommel undersize is diverted to the sluice box. The equipment for washing, while the oversize is discharged to the dump.

PLACER GOLD OCCURRENCES IN NEVADA

Gold placers of either actual or potential economic importance are distributed in 14 out of the 17 counties in the State. As indicated on the accompanying map (Plate I), most of the old placers are in the northern and western parts of the State. The more important placers, based on past production, are indicated by solid circles on the map, while new placers and those of minor importance are indicated with open circles. In the following pages data on the placer deposits are given by county and districts. No doubt other placers occur in the State, and with an increase in prospecting, due to curtailment in other industries, new deposits will be found. Much of the placer activity in recent years has centered about the better known districts. Although the results in some of these districts have been discouraging, many small scale prospectors have been able to obtain a living wage by searching for gold in areas of virgin ground that were overlooked in past operations.

NEVADA STATE BUREAU OF MINES
 UNITED STATES BUREAU OF MINES

NEVADA PLACER DISTRICTS

- CHURCHILL COUNTY—
 1. Eagleville (Hot Springs).
 CLARK COUNTY—
 2. Eldorado (Colorado, Nelson).
 3. Moapa.
 DOUGLAS COUNTY—
 4. Buckskin (Smith Valley).

ESMERALDA

MAP OF NEVADA SHOWING PLACER MINING LOCALITIES



36°

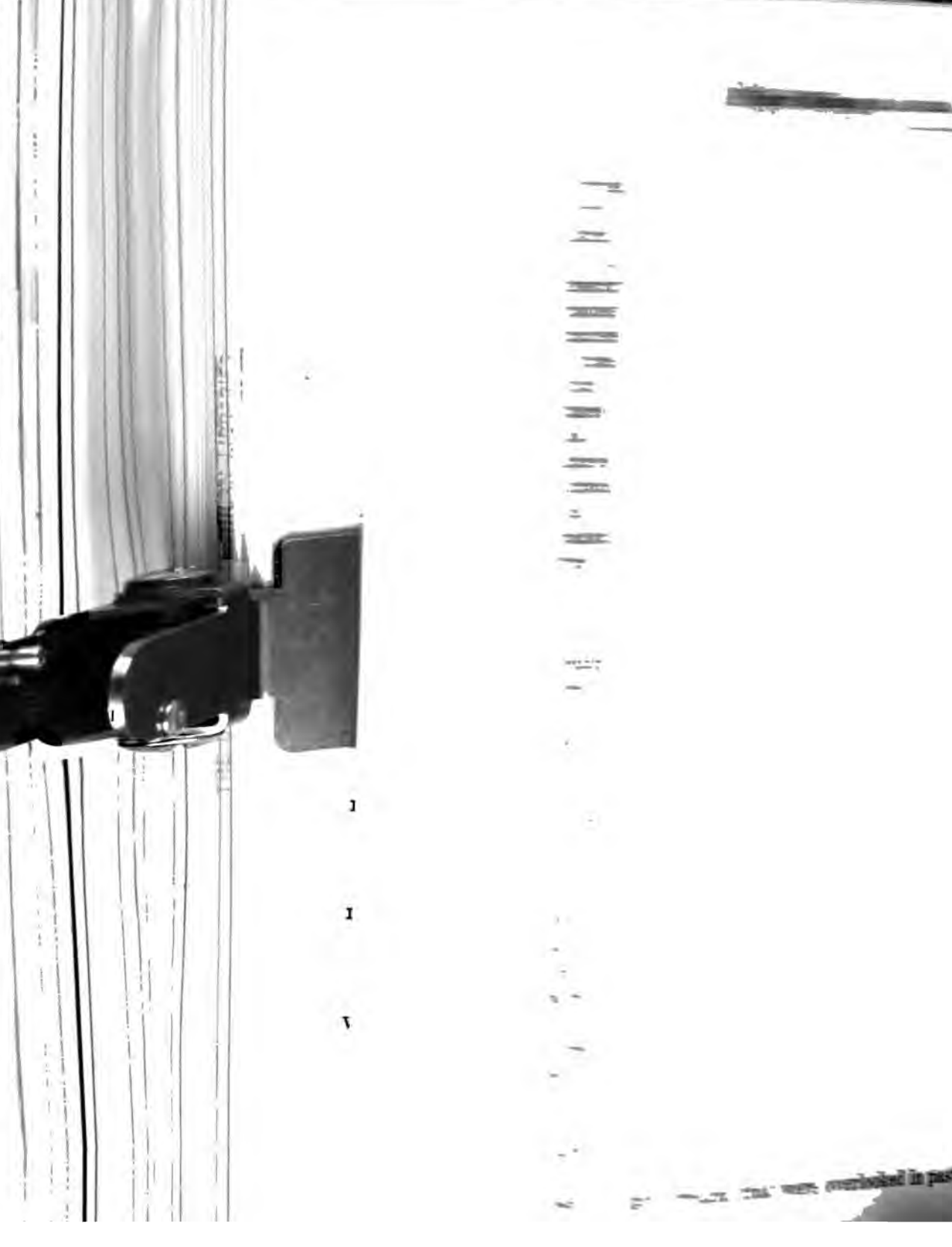
35°

120°

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117°



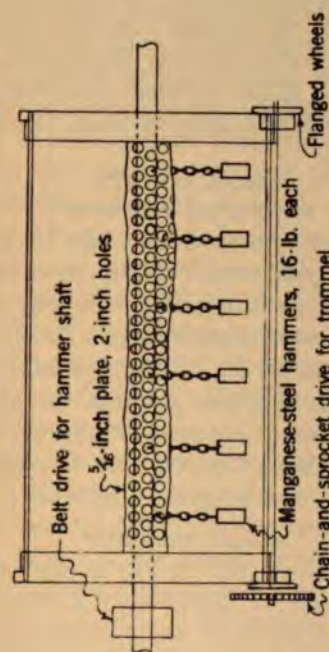
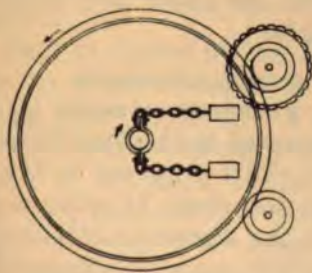


Figure 10. Quenner Disintegrator.



**CHURCHILL COUNTY
EAGLEVILLE DISTRICT**

The Eagleville or Hot Springs district is in Churchill County south of the old mining camp of Fairview, near the County line. A small amount of placer gold was recovered in 1906 from prospecting operations. After a short period of prospecting the placer activity ceased. In 1931 placer gold was discovered in the district in the canyon south of the Eagleville mine. This gold is rough and finely divided, and the gravel is coarse, indicating that the gold was derived from the gold-bearing gravel of the Eagleville mine.

**CLARK COUNTY
ELDORADO DISTRICT**

The Eldorado district, also known as Colorado district, includes Eldorado Canyon which drains into the Colorado River. It is in the southern part of Clark County near the Arizona border. The district was discovered in 1857, and in 1861 as the Colorado district. The principal product of the district has been from the lode mining operations. Placer gold is reported to have been discovered in the canyon, but as there is no record of any production it may be assumed that the placer deposits are not of great importance.

MOAPA DISTRICT

A placer gold discovery was made in this district in the bottom land gravels of the Muddy River, 40 miles from Las Vegas. The gold deposits were found, according to the report, while a party was searching for silica sand. It is reported that the gold is flourey, or very finely divided. A group of men organized a company in 1931 to prospect the district to determine the extent of the placer gold occurrence. No production has been made.

**DOUGLAS COUNTY
BUCKSKIN DISTRICT**

Placer gold was discovered in the Buckskin district in 1931, by Fred Hughes. This discovery is 2½ miles north of the old Buckskin mine, and about 14 miles northwest of Tonopah. The district is in the western foothills at the north of the Singatse Range, which separates Mason Valley from the Tonopah Valley.

A large number of claims have been located. A lease was granted on the portion of the original discovery ground which produced in the neighborhood of \$1,000.

The original discovery of placer gold was in a small,

about one-half mile in length, tributary to Spring Canyon. The rich gravel was found in a shallow depression behind a hard rib of rhyolite tuff crossing the ravine. This depression is about 50 feet long and 10 feet wide, and is a natural concentration area. Lying on the rough rhyolite bedrock is a stratum of sticky brown clay, mixed with sand and small angular fragments of rock. This clay is covered with less than a foot of unconsolidated sand and grit. Some of the clayey gravel yielded \$1 to the pan. Several hundred dollars worth of gold was taken from this area. The owners put about five cubic feet through a small concrete mixer to disintegrate the clay and gravel, and this yielded \$75 in gold and also a considerable amount of black sand concentrate containing some gold. Placer gold is found in numerous other places in the vicinity, but more prospecting and sampling must be done to determine the extent and gold content of the auriferous gravel.

In the upper part of the ravine, where the original discovery was made, a small leased area of placer ground is being worked by C. F. Scott and Sam C. Case. Here the soil and gravel is from three to five feet deep and lies on a decomposed bedrock. In working the ground, the soil and gravel above bedrock is scraped to one side with a Fresno scraper drawn by a team of horses. Although this surface material carries gold to a value of about \$1 per cubic yard, it is too low grade to treat profitably with the present equipment. After the top soil is removed the decomposed bedrock is plowed to a depth of 10 inches, and loaded by means of the horse-drawn scraper into a small automobile truck for transportation to the treatment plant. The loading arrangement is shown in Figure 11. The treatment plant is located about 3½ miles from the loading point at a farm where an artesian flow of water is obtained.

The treatment plant is shown in Figure 12. It consists of a shoveling platform on which the gravel is unloaded from the truck, and a washing plant comprising a shaker box and sluice. The capacity is 16 cubic yards per eight hours.

The novel feature of the plant is the shaker box which is employed for the dual purpose of disintegrating the clayey material and for screening out the oversize. From the shoveling platform the placer material is shoveled into the shaker box by hand, and at the same time water is run in to wash it. The shaker box is made of sheet iron and it is 5 feet long, 30 inches wide and 18 inches deep. Six inches above the bottom of the box are two screens. The lower screen is made of sheet iron with ¼-inch holes, and this supports an 8-mesh woven wire screen.

The shaker box is suspended from a rod by two hangers. A horizontal shaking motion is imparted to iron rods eccentrically connected with a shaft which by belt drive to a 60-horsepower automobile engine. The radius of the eccentric is 6 inches and the number of strokes per minute is 60. To assist in the disintegration of the clay, stones 5 to 6 inches in diameter are placed in the box.

The oversize material is discharged at one end into cars for transportation to the dump; the minus 8-mesh material along with the gold is discharged into a sluice, the head of which is directly below the shaker box. The sluice is constructed of 2-inch plank and is 10 inches wide and 8 inches deep.



Figure 11. Loading placer material into truck with Fresno shaker box. The shaker box is 10 feet long, with wings at the upper end to catch the material from the shaker box. Coarse woven wire screen is placed at the bottom of the sluice box to act as riffles.

The first 70 yards of gravel treated in the plant is valued at \$889, an average of \$12.70 per yard. The cost of operation was about \$1.50 per cubic yard. The gold assay was 0.15 ounces per ton and was finely divided.

GENOA DISTRICT

The Genoa district lies upon the east slope of the Sierra Nevada Range in Douglas County, a short distance west of the town of Genoa. The district was organized in 1860 and a large amount of development prospecting was done on the lode deposits with discouraging results. Placer deposits of Tertiary age have been prospected to some extent, but the only record of

production was in 1916, when a small amount was recovered in prospecting. The district is of special interest because the gold is found in ancient Tertiary gravels.

MOUNT SIEGEL DISTRICT

The Mount Siegel placer district lies north of Mount Siegel, on upper Buckeye Creek in east Douglas County, about 20 miles east of the town of Minden. The placers occur at an altitude of about 7,000 feet above the sea level. They are of Tertiary age. It is believed that these washed, and rewashed, gravels lie in a bed of a Tertiary stream which coursed easterly from the high Sierra Nevada Range. The placers were prospected in 1911 and that year produced \$1,070. This gold had a fineness of 880. The



Figure 12. Gravel washing plant in the Buckskin district.

Buckeye and Ancient Gold Placer properties have produced small amounts of gold intermittently by small scale methods. The total production in the district has been about \$5,000.

ELKO COUNTY

ALDER DISTRICT

The Alder or Tennessee Gulch district lies in north central Elko County, 10 miles south of Rowland. Considerable activity in placer mining prevailed in the early days as is indicated by the old placer tailings on Gold Run Creek, one-half mile north of the Baker Ranch. In 1927 men were prospecting for placer gold in the district, and the recovery of an ounce or two of gold was reported.

AURA DISTRICT

The Aura district, also known as Bull Run, Cerro Columbia districts, is in the central part of the Bull Run Mountains, 20 miles southwest of Mountain City, in northern Elko County.

The placers were discovered by the pioneers, and in the seventies some placer mining was done. In 1905 a company was organized to mine on a larger scale. In 1925 a ditch was constructed to bring water from Blue Jacket Creek by hydraulicking. After a short time operations ceased, and in recent years there has been no activity in the district.

CHARLESTON DISTRICT

The Charleston district, also known as the Copper Mountain or Cornwall district, is in northern Elko County, about 10 miles north of Deeth. It is on the south side of the Jarvis Mountains, and in particular on the south side of Copper Mountain which rises to a height of over 10,000 feet above sea level. The district came into existence in 1876 when placer gold was discovered four miles to the north of the townsite on 76 Creek near the base of Copper Mountain. The bed of 76 Creek produced considerable placer gold in the years following the discovery of it, and as water is available in that creek it was worked extensively. Lying between 76 Creek and the Bruneau River are the Pennsylvania Gulch, Union Gulch, Dry Ravine, and Badger Creek, in which placer deposits were also worked in the early days.

The placer gravels of the Charleston district extend along both sides of the Bruneau River. They consist of well-rounded pebbles derived from rather coarsely crystalline rhyolite, which is one of the principal rocks of the district. The smaller amounts of quartzite and granite pebbles. In places the gravels are 50 feet thick, and often rest upon a light-colored bed of decomposed tuff which may indicate the bottom of old river beds. A long period of erosion and working over the stream beds is indicated by the well-rounded character of the pebbles. The placers of the Mountain City district, 35 miles to the east, seem to be of similar origin.

In 1907 a Utah company, at a cost of \$25,000, built a ditch several miles in length around the south slope of the mountain in order to bring water from a tributary of 76 Creek to hydraulicking the gravels in the Badger Creek area. The stream normally carries but little water and it is reported that water flowed through the ditch for a short time only each season.

In the spring of 1932 a Denver group obtained an option on the Prunty ranch, which is traversed by the Bruneau River and Badger Creek. Considerable prospecting was done on the ground and it was estimated that the gravel contained an average of 75 cents per cubic yard. In places the gravel is 30 feet thick. Upon the east side of Bruneau River is a gravel mesa through which Badger Creek flows. Many pannings made along Badger Creek show small amounts of gold. A power shovel and sluice operation is contemplated for 1933.

In the spring and summer of 1932 thirty or more men were engaged in placer mining in Pennsylvania, Union and Dry Gulches. Most of the placer mining is during the spring seasons, when



Figure 13. Sluicing near the mouth of Union Gulch, Charleston District.

sufficient water is obtainable for small scale sluicing operations. Figure 13 shows a sluicing operation near the mouth of Union Gulch. The average yield from these small scale sluicing operations nets the workers less than wages. The gold recovered is quite fine.

GOLD BASIN DISTRICT

The Gold Basin or Rowland district is located in north central Elko County within a few miles of the Idaho-Nevada boundary line. The district has never attained any appreciable production of placer gold.

In 1931, A. S. Longwill carried on a small scale sluicing operation on the north fork of the Bruneau River. He constructed a small reservoir for impounding water, and treated a small amount of gravel which yielded gold value of less than \$1 per cubic yard.

ISLAND MOUNTAIN DISTRICT

The Island Mountain or Gold Creek district is at Island Mountain, 75 miles north of the town of Elko and about 25 miles from the Idaho-Nevada State line. It is on Gold Run, one of the tributaries of the Owyhee River. The district takes its name of Island Mountain from an isolated mountain on which rises at least 1,000 feet above the surrounding country. The average elevation of the district is about 8,000 feet above sea level.

The district was discovered in 1873 and soon became one of the most prominent placer areas in the State. The early operations were confined to sluicing. In subsequent years a large investment was made in ditches and pipe lines for the operation of hydraulic giants. The ditch was five miles long and carried water from the Owyhee River to a point near the placer where a head of 300 feet was obtained for the operation of the giants. The work resulted in the recovery of much gold. In addition to this, considerable panning and rocking was done by earlier miners. According to an early report of the State Mineralogist for Nevada,⁸ some of the claims on Hope Gulch yielded 100 per pan and as much as \$30 per day per man was obtained by the rockers. Although the best ground has now been worked, men have mined there in recent years with some success. The gold averages about \$10.50 per ounce. The principal reason for more extensive operations in recent years has been the lack of sufficient water. Water is available only during the spring months.

MOUNTAIN CITY DISTRICT

The Mountain City, also known as the Cope, district is located in eastern Elko County on the Owyhee River in the Bull Mountain area. Silver-gold ore was discovered in the district by Louis Cope in 1869, and the town of Mountain City was founded. Placer gold was found in the Owyhee River, but little attention was given to it for the first prospecting was largely confined to the vein gold.

In the middle seventies placer gold was discovered on Hope Gulch, north of Sugar Loaf Peak, which was mined for a length of half a mile. Many stacks of old mining equipment are evidence of the activity of the early placer miners. In the biennial report of the mining activity in the State for 1876,⁹ it is stated that the placer mines on both sides of the Owyhee River yielded well. From 1870 to 1890 much of the gold was produced in this district.

⁸Stretch, R. H. Biennial Report of the State Mineralogist, State of Nevada, 1873-1874, pp. 27-28.

⁹Stretch, R. H. Biennial Report of the State Mineralogist, State of Nevada, 1875-1876, p. 25.

done by R. M. Woodward and Alley Harris and associates, who constructed a ditch from Mill Creek and hydraulicked part of the ground.

Small scale placer mining operations have been carried on intermittently in recent years, but no large amounts of gold have been produced. In 1915 the production of placer gold from the district was less than \$200, and in 1921 it was \$1,776.

In 1932, prospectors, using a patented placer machine (Figure 14), worked a short time in Hansen Gulch, which is a tributary to Grasshopper Gulch, but inasmuch as the ground had been worked previously, the results were discouraging.

The Dorins Concentrating and Amalgamating Machine, used



Figure 14. Placer machine in Hansen Gulch, Mountain City District.

by these prospectors, is a narrow iron box about 3' high, 3' long and 16" wide. The gravel is shoveled into the top, and aided by a vibratory motion and a stream of water, passes over a system of enclosed screens and mercury traps. A small gasoline motor supplies power for the machine and a $1\frac{1}{2}$ centrifugal pump. The water flows from the machine into a box and is reused.

In September, 1932, a group of miners were preparing to ground sluice what are thought to be virgin bars on the Owyhee River, two miles north of Mountain City within the boundary of the Duck Valley Indian Reservation. Numerous pannings indicated that sufficient gold was present to justify working the bars. The gold is coarse and well rounded. Another group of men are planning to begin hydraulic operations in the spring of 1933 along the river north of the afore-mentioned locality.

VAN DUZER DISTRICT

The Van Duzer district is in the Bull Run Mountain to the Mountain City district on the south and the Au on the northeast. Placer gold was first discovered in in 1893 by Rutley W. Woodward, who operated several is reported to have taken out gold to the value of \$ subsequently sold the ground to Alley Harris. Harris worked the ground until 1910. Harris reported that paid him an average of \$5 per linear foot of creek bed feet, a total of \$37,500. Most of the first placer mini hand shoveling into sluice boxes, although for a time used two small hydraulic monitors (Figure 15).

The gravels are a mixture of subangular and well-ro bles and contain few large boulders. The average de gravel is about 10 feet. Some of the gold was probab



Figure 15. Hydraulic mining on Van Duzer Creek, Elko County

from the ancient fluvial gravels which cover large northern Elko County. It is rather coarse, and some o rounded by stream action. Nuggets have been found oc The gold is worth about \$17 per ounce.

In 1932 the placer ground was leased to a Los Angele who employed four men. They shoveled the gravel by a conveyer belt which discharged into a trommel. Th oversize was discarded as waste and the undersize div sluice. There is always sufficient water to carry on s ing operations.

TUSCARORA DISTRICT

The Tuscarora district is on the east slope of Mount Blitzen in the Tuscarora Range. Placer gold was discovered there in 1867 by the Beard brothers. The news of this strike soon reached Austin, Nevada. Bound for the new strike, over 100 men left Austin in a band that year, well equipped and armed against hostile Indians who then made prospecting in Nevada both adventurous and dangerous. Many of these pioneers remained at Tuscarora and found the new placers profitable.

J. Ross Browne, a distinguished mining geologist of the time, described the placers as being three miles long, five feet deep, and rather narrow. He predicted that a score of men could make only from \$10 to \$20 per day by hand washing the gravels. The placers produced \$7,000,000 from 1869 to 1909.

Between 1868 and 1872, from 150 to 250 Chinese were placer



Figure 16. Placer tailings from old workings in the Tuscarora District.

mining on ground leased from American owners. The early mining was by ground sluicing, rocking and panning, with water supplied through two ditches. The Beard brothers' ditch was six miles long and brought water from McCann Creek. The other ditch was also six miles long, and conveyed water both from Three Mile Creek and Six Mile Creek. These pioneer ditches have been abandoned.

The Chinese produced from \$2 to \$15 per day.¹⁰ From 1873 the placer mining activity rapidly declined, and in recent years

¹⁰Whitehill, H. R. Biennial Report of the State Mineralogist, State of Nevada, 1871-1872, p. 24.

only small sporadic placer operations have been carried on. A surprising feature of the early placer operations is the small area worked in proportion to the production of \$7,000,000 which the Tuscarora placers are credited. The work was confined to gullies on gently sloping sagebrush country bordering the northwestern end of Independence Valley. The flat, shallow ravines draining south into Independence Valley yielded the greater part of the production. Typical old workings, now almost hidden by sagebrush, are shown in Plate I.

In 1931 a group of men sluiced the gravel in Revere Gulch, a short distance west of Tuscarora. Water was obtained from several springs in the vicinity. This work was confined to the lower part of the gulch in an area which may have been overlooked by the early placer miners. In 1932 others were working old gravel tailings in the upper part of the gulch.

In 1931 gravel was sluiced in Stovepipe Gulch, water for the work being obtained from the old Stovepipe mine shaft.

ESMERALDA COUNTY

KLONDYKE DISTRICT

The Klondyke, or Southern Klondyke district, is 14 miles west of Tonopah in the Southern Klondyke hills in east Esmeralda County, near the Nye County border. The district was discovered by Court and Bell in 1899, but it is reported that Chinese had placered there in the middle seventies. In the years following the discovery of the lode deposits, a small amount of mining was done by dry washing methods. The results were discouraging, and in recent years there has been no placer mining in the district.

TULE CANYON DISTRICT

Tule Canyon or Lida district is in south Esmeralda County in the Silver Peak Range. Placer gold was discovered in Tule Canyon, about 10 miles south of the town of Lida in 1899. The deposits were actively worked for a number of years toward the westward. The placer deposits are found over an area of about 100 square miles, but owing to the scarcity of water the deposits have been worked only on a small scale. The only water available in the immediate vicinity of the deposits is derived from a few springs.

Small placer operations have been carried on in recent years, mainly by dry washing. Prospecting in Tule Canyon has shown that the gravels will average about \$1.25 per cubic yard of rock. Nuggets worth as much as \$50 have been found. The extent of the deposits justifies further prospecting.

PIGEON SPRINGS DISTRICT

The Pigeon Springs or Palmetto district is 60 miles southwest of Tonopah in the Palmetto Mountains. The elevation is about 6,000 feet above sea level. The district was discovered in 1866. The placer ground covers several square miles and is near the California-Nevada boundary line. The early activities gave good results by dry washing with small scale equipment. The greatest activity in the district was in 1914, and since then it has produced a small amount of placer gold.

A power shovel and three dry washing machines were in operation on the Rigsby property in 1929 and 1930, but the results of this work could not be determined.

TOKOP DISTRICT

The Tokop district, which is also known as Gold Mountain, Bonnie Claire, or Oriental Wash district, is in the southern part of Esmeralda County near the California-Nevada boundary line. The district was discovered in 1866 and attracted considerable attention when, in 1871, rich gold veins in the Oriental mine were discovered. A small amount of placer gold has been produced from the district in past years, but at present (1932), the placers are inactive.

EUREKA COUNTY**LYNN DISTRICT**

The Lynn district is in northern Eureka County in the Tuscarora Range at the head of Lynn Creek, about 20 miles northwest of Carlin. The placer deposits, which cover a large area, were discovered by Joe Lynn in 1907, and following their discovery a brief boom ensued. Since their discovery the placers have been worked intermittently by small scale methods. The total production of gold is estimated to be a little over \$100,000.

The district is situated among high, well-rounded sagebrush covered hills, composed largely of rhyolitic flows. The rhyolite is traversed by a number of small quartz veins and sheeted zones, the erosion of which supplied the material for the placer deposits. The gold is coarse, rough, and nearly pure. The gravels are fairly coarse, and contain a fair proportion of medium size sub-angular boulders. Bismuth oxide and sulphide have been found in the placers. The greatest accumulation of gold is in the upper portions of the ravines, having traveled only a short distance.

In 1932 the principal placer mines being worked were the Arrowhead, Graves, and Bulldog.

The Arrowhead placer is in Sheep Canyon Creek on the west slope of the mountains and is worked by K. C. Nelson on a royalty

basis. During the 1931 season Nelson recovered 250 gold from his operation. This gold averaged 920 fine. were employed. In 1932 operations were started in the yield is expected to be better than for the year 19

An unusual method is employed by Nelson for reco gold. The equipment consists of a reservoir for imp small flow of water (about 2½ miners' inches), a har power driven rocking sluice box or long tom. The gra creek bed is loosened with a horse drawn, spring too while water is flowing over it. (See Figure 17.) In large proportion of the soil and clay is washed from The partly washed gravel is then moved into a pile wi drawn scraper. The gravel is shoveled from the pile by



Figure 17. Loosening gravel with spring tooth harrow, Lynn

the long tom, which is 16 feet long, 10 inches deep, and wide, and is equipped with riffles. The sluice is set and shaken from side to side by means of eccentric rotation driven by a 1½-horsepower gasoline engine. Its about four cubic yards per hour (Figure 18). The ordi garian type riffles made of wood strips 1 by 2 inches 2 inches apart in the lower end of the sluice. In the the riffles consist of 2-inch plank with numerous holes diameter. This board is supported 2 inches above the the box by a wooden grating. This short riffle is e saving the gold and catches about two-thirds of the tot recovered. The upper end of the sluice is cleaned up quently than the lower end. The lower riffles are ma

-foot sections. Notwithstanding the small amount of water used, tailings from the box contain less than 5 cents per cubic yard.

Early in the season when more water is available, ordinary sluice boxes are employed. When all water flow ceases, usually about June, dry washing machines are resorted to and the work continued until fall. The placer season is 6 or 7 months per year. Large dumps of tailings from the dry-washing machines have accumulated which are said to contain unrecovered gold. It is planned to sluice the dry wash tailings some time when water is available.

George Graves is working adjoining ground, using a patented power rocker for recovering the gold (Figure 19). The outside



Figure 18. Power driven sluice box, Lynn District.

Dimensions of the rocker are 27 inches wide and 49 inches long at the top and 21 inches by 49 inches at the bottom. It is 24 inches high in front and 21 inches in the rear. The machine rests on wooden rockers. The screen at the head consists of an iron plate perforated with $\frac{5}{8}$ -inch round holes spaced on $2\frac{1}{2}$ -inch centers, and staggered. Beneath the screen are three aprons made of wood and canvas, placed at angles so that the fine gravel which falls through the screen travels over each apron, following a zig-zag course from end to end of the box until it reaches the outlet at the bottom. Each apron has a fall of 3 inches per foot. The frame of the aprons is made of $1\frac{3}{4}$ by $\frac{3}{4}$ -inch wood strips, with several transverse strips to support the canvas. On top of the canvas are $\frac{1}{2}$ by $\frac{1}{4}$ -inch wood riffles. The box is



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The machine is worked by hydraulicking on

scale. Water is brought by gravity flow to a small reservoir near the property, from which it is drawn through a 3½-inch diameter hose with a 5⁄8-inch nozzle. The water is under a head of 50 feet. During the nine years this placer has been worked by the present owner it has paid very well, but the pay gravel is nearly exhausted.

MAGGIE CREEK DISTRICT

The Maggie Creek district, also known as the Schroeder or Susie Creek districts, is in the Tuscarora Range in northwest Eureka County near the west boundary line with Elko County, about 10 miles northwest of Carlin. A small amount of placer mining has



Figure 20. Side shake concentrating table used in Lynn District.

been done from time to time at the head of Maggie Creek, but no large production of placer gold has been recorded.

HUMBOLDT COUNTY GOLD RUN DISTRICT

The Gold Run or Adelaide district is in southwestern Humboldt County on the east slope of the Sonoma Range. The Bonanza, Gold Run, and other small placer properties about 10 miles south of Golconda were worked mainly by lessees in a sporadic manner from 1914 to 1922. The gravel was mined by sinking shafts and drifting along bedrock. Rockers were employed for the recovery of the gold. During 1932 there was considerable activity. Several men were working in the district, and very rich gravel was being worked on one claim. The total production of placer gold prior to 1930 had been in the neighborhood of \$3,000.

PARADISE VALLEY DISTRICT

The Paradise Valley district, also known as or Spring City district, is on the east slope of Range, eight miles northwest of the town of The lode and placer deposits were discovered in the bulk of the production has been derived from the placers have also been worked.

In recent years there has been very little placer district.

REBEL CREEK DISTRICT

The Rebel Creek district, also known as New Columbia or New Creek district, is on the west slope of the Santa Rosa



Figure 21. Cleaning up with hand rocker at Bulldog place

54 miles north of the town of Winnemucca. The first prospected in 1907. Placer deposits were found on a small scale at the foot of the Santa Rosa Range, 54 miles north of the town of Winnemucca. The production of

VARYVILLE DISTRICT

The Varyville district is in northwest Humboldt 100 miles northwest of Winnemucca. It is sometimes called the Columbia or Leonard Creek district. It was originally as the Columbia district in 1875, and lode mining a number of years. The placers were discovered the lodes, and have been worked intermittently on to the present.

In 1931, 1,500 acres above the Montero ranch

Creek for a distance of about two miles was under investigation as placer ground by a company called the Leonard Creek Placers, Ltd. The ground was tested and sampling indicated that a considerable yardage is available which has an average gold content of 50 cents per cubic yard. The average depth of the gravel is about 20 feet, and in places over 35 feet. The success of the enterprise may depend upon obtaining an adequate water supply from the Leonard Creek ranch, which owns the Leonard Creek water. Recent work has been directed toward the development of additional water by sinking wells at the lower end of Leonard Creek Canyon.

In 1932 a number of miners were sluicing, rocking or dry washing on Teepee and Snow Creeks, tributaries of Leonard Creek. During the spring season, water for sluicing is obtained from the run-off derived from melting snows. Later in the year when this water supply fails dry washing methods are employed.

DUTCH FLAT DISTRICT

The Dutch Flat placers are 18 miles northeast of Winnemucca and 18 miles north of Golconda. This is one of the old placer areas in Nevada, although the year of its discovery is unknown. In 1893, about \$75,000 in placer gold was recovered by sluicing. The water for sluicing was obtained from the Little Humboldt River, six miles distant.

The placer area has a length of about 8,000 feet and a width varying from 300 to 2,000 feet. The pay streak is from 3½ to 6 feet above bedrock, and the overburden which carries subordinate values is from 8 to 20 feet deep. The greater part of the gold is very fine, and the average value of the paystreak is reported to be about 60 cents per cubic yard. The gold is very pure, having a fineness of about 940.

The last serious attempt to work the placers was when a company organized in Salt Lake City took over the ground formerly held by the Dutch Flat Gold Mining Company. Twenty acres sampled by the Salt Lake City company averaged 31 cents per cubic yard, and contained 375,000 cubic yards of gravel averaging 15 feet in depth. The equipment installed consisted of a 4 by 16-foot rotary screen, a drag line scraper, sluice, and tailings elevator. The gravel was excavated and was fed into the revolving screen by the drag line scraper. The oversize from the screen was discharged to a waste pile by a tailings elevator. The undersize was treated in the sluice. The company operated only a short time.

LANDER COUNTY**BATTLE MOUNTAIN DISTRICT**

The Battle Mountain district is in the Battle Mountain north central Lander County. It covers a wide area and includes the placers in Copper and Rocky Canyons, Duck Creek, Copper Basin, Galena on Duck Creek, and the old abandoned mining camp of Bannock. Lode mines of the district were discovered in 1864, but the placers were not worked until about 1909. When originally organized it was in Humboldt County, but was ceded to Lander County.

Although lode mining has been the principal industry of the district, a large number of small placer properties have been productive from 1909 up to the present time. From 1930, inclusive, the placer gold production was nearly \$100,000. In 1910, the year of the first recorded placer production, the output was \$5,627, and steadily increased until it reached a peak in 1915 of \$160,596. From 1915 it slowly declined to \$10,000 in 1929. In the last few years the district has witnessed a revival in placer mining, and a large number of small scale operations have been active, generally with fair returns. In 1930, 100 men were engaged in placer mining. In 1931 and 1932, 150 washing machines were operating in Box Canyon. In the fall of 1932, 40 men were placering in Copper Canyon.

The most productive areas are at the mouth of Copper Canyon and in Black Canyon, near Bannock. Much of the gold is coarse and ranges from 830 to 870 in fineness. According to the series reported by various operators a considerable portion of the placer areas will average above \$1 per cubic yard. The largest nugget reported in the Bannock area weighed 3.51 ounces. In 1931 a nugget was found in the Copper Canyon area on the site formerly known as the Dahl placer which had a value of \$100.

Most of the placer gulches in the district are V-shaped. The gravels are sub-angular, and roughly stratified by stream action. The principal values are found on, or directly above the surface. In some cases values are found throughout the gravel. Limonite, quartz, and pyrite are occasionally associated with the gold, indicating that the gold is all local in origin and has not traveled far from its source.

In the recovery of the gold, dry washers and rockers are generally employed for small scale operations. In some cases water has been hauled as far as five miles to work the rockers. Where the gravels are deep and the values are concentrated largely on bedrock, drift mining is done.

The principal producers in the district were the Dahl placer and the Homestake Consolidated Mining Company, both of which are in Copper Canyon. The latter company controlled 2,400 feet along the canyon. There is a scarcity of water in proximity to these placers which has proved a drawback to more extensive operations. In Copper Canyon the bedrock is smooth and the gravel, from 40 to 50 feet in depth, contains few large boulders. The gold is found over a width of about 125 feet, and in general the gravel is reported to have averaged 75 cents per cubic yard from the surface down to within a few feet of bedrock. Greater values are obtained in the few feet directly above bedrock.

The Dahl placer is owned by Dudley Wilson. The ground is being worked by Wilson and by lessees on a royalty basis.

The Wilson placer operation is carried on by sluicing. The



Figure 22. Gravel bins above sluice at Wilson Placer, Battle Mountain District.

ground is mined by drifting on bedrock. Entry to the mine is made by a tunnel parallel to the course of the canyon. This tunnel has a total length of 2,300 feet, 1,600 feet of which was driven in gravel before the bedrock was encountered. The gravel ranges from 35 to 50 feet in depth. Three separate channels have been found, all of which contain gold. The three channels are worked by lateral drifts from the main tunnel. The gravel is trammed to the surface, and dumped into a series of bins from an elevated trestle a short distance from the portal of the tunnel. The trestle and bins are shown in Figure 22. From the bins the gravel is fed into a sluice several hundred feet long, which is equipped with light steel T-rail riffles. The sluice is set on a grade of 7 inches

per 10 feet, and is 16 inches wide and 12 inches deep. supplied to the sluice from a reservoir having a capacity of 200,000 gallons. The water is piped to the reservoir from Battle Mountain Creek, three miles distant.

In addition to the above operation old placer tailings are reworked by sluicing. The tailings are transported to the sluice with a Sauerman drag line scraper, which has a capacity of half cubic yard. The average distance of scraper haul is 100 feet, the greatest distance being 200 feet. The scraper is powered by a 22-horsepower gasoline engine mounted on a truck. The scraper is very convenient in moving from place to place. When moving from one place to another 200 feet the scraper makes a round trip every three minutes.

The gravel comprising the tailings is subangular and the



Figure 23. Transporting old tailings to sluice with drag line scraper. Battle Mountain District.

rocks are 6 to 8 inches in diameter. The average depth of the tailings is six feet, and although the gold content is low, the operation is profitable. Figure 23 shows the scraper discharging into the sluice. The general layout of the Wilson placer operation is shown in Figure 24.

STEINER CANYON DISTRICT

The Steiner Canyon or Bobtown placer is located about 10 miles between Austin and Battle Mountain near Bobtown, on the Nevada Central narrow gauge railroad. During the late seventies gold was discovered here in a well which was used to supply water for a stage station. At the point in the v

placer gold was discovered an abundant flow of water was encountered and no further attention was given the discovery of placer gold until recently, when an attempt was made to sink the well on down to bedrock. The flow of water proved too great to handle with the equipment available, and the prospectors were forced to sink a shaft on a new site higher up the canyon. Here also the water was encountered at a depth of 40 feet and pumping equipment has been installed in an attempt to reach bedrock. Placer operations at Steiner Canyon are still in the prospecting stage.

TENABO DISTRICT

The Tenabo district, also known as the Campbell, Bullion, and Lander districts, is in northern Lander County about 25 miles



Figure 24. General view of Wilson placer operations, Battle Mountain District.

southeast of Battle Mountain. Although lode mining has been carried on in the district since the seventies, not until recent years has any attention been given the placer deposits.

The placers consist of clay and gravel, parts of which are loosely cemented. The gold is associated with much black sand and is finely divided.

Most of the known placer area in the district is owned by a company which grants leases. In 1931, a Salt Lake City company installed equipment to work the placers on a large scale. A specially designed machine was erected which is reported to have a capacity of 500 cubic yards per day. Operations have been hampered by the lack of adequate water, most of which is obtained

from two mine shafts in the vicinity. It is hoped this supply by sinking a well in the valley about the placer ground. A test run made in 1931 is said to have yielded \$1,000 in gold in 32 hours.

IOWA CANYON DISTRICT

The Iowa Canyon district is about 16 miles long. Placer gold has recently been discovered in the vicinity of a ranch of Joseph Phillips. A shaft was sunk in an attempt to reach bedrock, but a large flow of water entered. The operations have not gone beyond the first stage.

LYON COUNTY

GOLD CANYON DISTRICT

The Gold Canyon district, also known as Chinatown, Devil Gate, and Dayton districts, is in Gold Canyon on the slope of the Virginia Range in western Lyon County. It was discovered by Abner Blackburn in 1849 at the mouth of Gold Canyon near the site of Dayton. This was the first discovery of placer gold in Nevada. The district has been the scene of long-continued placer operations, and although the extent of the old workings is unknown it is undoubtedly quite large.

The Gold Canyon placers were derived from the erosion of the lodes of the Comstock and Silver City. The Gold Canyon spreads out into an alluvial fan in which considerable gold has been found at varying depths. Although the area is scarred with shafts and pits, and ramify numerous gravel drifts, it is not impracticable to dredge the gravels underlying the town of Dayton and the area may be rich enough for gold dredging. Southwest of Dayton the Carson River has etched out a narrow but fertile valley, the north side of which emerge ravines from the Silver City districts. Engineers have considered the area for dredging, but the land is closely held by small farmers.

The first dredge in Nevada was constructed in 1898 on the Carson River below Dayton, and it was of the clamshell type. The plan was to recover amalgam and quicksilver from the tailings of stock mills. However, the dissemination of amalgam had been too widespread and the operation was unsuccessful.

A second dredge was installed in the district in 1900. This dredge was built by the Gold Canyon Dredging Company, a subsidiary of the Metals Exploration Company, which

was working mines on the Comstock lode. The placer holdings were between Silver City and Dayton, and consisted of 1,017 acres, 297 of which were patented, and the remainder held under lease. It is reported that 200 acres of the sampled ground range from 15 to 49 feet in depth and contained from 40 to 90 cents per cubic yard. The placer ground was partly stream bed, and partly a terrace lying southwest of Gold Canyon and sloping toward the Carson River. The elevated site of the dredge necessitated ample water supply for the seepage losses were large. Water was obtained from the Virginia and Gold Hill Water Company which owns the water system supplying Virginia City and Silver City. It was brought in by 4,500 feet of 8-inch wooden stave pipe and 3,800 feet of ditches.

The dredge was the close connected bucket type and had a capacity of 5,000 cubic yards per day. Each bucket held 9 cubic feet and the digging depth was 40 feet. The hull was of steel, 46 feet wide and 108.5 feet long. The deck seams and upper side seams of the hull were arc welded, while all the main construction joints were riveted. The total weight of the dredge was 900 tons, and the cost of construction was about \$250,000.

The dredge motors comprised a total of 500 horsepower. Power was purchased from the Truckee River General Electric Company.

The gold saving equipment on the dredge consisted of a receiving hopper, a revolving screen 5 feet in diameter and 38 feet long with 1½-inch round holes, sluices and riffles, and a tailings stacker. The sluices and riffles comprised a total area of 3,000 square feet. The tailings stacker was 120 feet long and consisted of a conveyer belt 34 inches wide. The main water supply was furnished by a 10-inch centrifugal pump.

The dredge operated for a period of three years and was then dismantled.

In recent years there has been very little placer activity in the district.

YERINGTON DISTRICT

The Yerington district, also known as the Ludwig or Mason district, is in the southern part of Lyon County in the vicinity of the town of Yerington. Although the district has been an important producer of copper since 1864, placer mining was non-existent until 1931, when several placer deposits were discovered. The more important of these are the Adams-Rice and the Guild-Bovard placers in the Singatse Range.

The Guild-Bovard placer is on an alluvial fan sloping southerly into Smith Valley, about two miles east of the old mining camp

of Buckskin. This placer is being prospected at the Yerington. The gravel is principally composed of partially altered angular rhyolite wash, containing but few boulders (figure 25).

The Adams-Rice placer is in a small dry canyon between Pass and Gallagher Pass, about eight miles northwest of Yerington. The original discoverers, J. S. Adams and Rice, sold to a Reno group which has done considerable work and prospecting on the deposit. Pumping equipment has been installed at a well in the valley east of the placer. For machinery has been set up in the canyon, and the gravels began in the fall of 1932.

The gravel in the canyon varies from 12 to 22 feet



Figure 25. Prospecting shaft on the Guild-Bovard placer, Yerington.

with an average depth of about 15 feet. It is composed of angular rocks containing no large boulders. Much of the gravel consists of finely divided dust and flakes with a tendency to float on water. The heavier gold is principally rough and unworked, but some washed and rounded colors are found. Insufficient work has been done to determine the total amount of gold in the gravel. The average gold content per cubic yard is about 0.5 ounces. About 35 test shafts have been sunk to bedrock. Each shaft is about 4½ by 6 inches in section, and the average depth is about 12 feet. The cost of sinking these shafts by hand with windlass and bucket is about \$1 per linear foot of shaft.

The samples obtained from these shafts were hauled about 10 miles to the sampling plant. The gravel is treated

rocker with water from a well in the edge of the valley. The sampling plant is shown in Figure 26.

A test of the pumping plant installed in the valley showed that 400 gallons of water per minute are available. A four-inch pipe line about three miles long has been laid from the well to the placer. Plunger pumps are used. The total head against which the water is pumped is nearly 1,000 feet.

A power shovel is used for excavating the gravel.

MINERAL COUNTY
HAWTHORNE DISTRICT

In 1909, during the mining excitement which followed the discovery of rich lode gold mines in the Lucky Boy district, placer gold was discovered about two miles south of Mt. Grant. In 1932



Figure 26. Equipment for sampling placer material at Adams-Rice placer, Yerington District.

it was discovered that profitable placer values lie five or six feet below the surface in a bed of volcanic ash. Sluicing operations on a small scale were begun with success, and an attempt has been made to increase the inadequate water supply by sinking to bedrock and installing a pump.

PINE GROVE DISTRICT

The Pine Grove district, also known as the Rockland and Wilson districts, is on the east flank of the Smith Valley Range in western Mineral County, 20 miles south of Yerington. Placer gold has been found in the district, but the deposits have not yet proved to be of sufficient importance to justify extensive working.

A small amount of placer prospecting has been carried on in the district in recent years.

RAWHIDE DISTRICT

The Rawhide or Regent district is in northwestern Esmeralda County near the Churchill County border. The local gold was discovered in 1906 and the placer deposits are said to be rich. The total production of the placers has been about 100,000 ounces of which was derived from small dry washing operations. The placers were actively worked for several years after their discovery. In recent years there has been only a little prospecting of placer mining in the district.

The placers occur in a canyon for a length of about 10 miles. At the south end of the canyon the gravels spread out over an alluvial fan. The gravels are 90-feet deep in places and the best values are concentrated on the bedrock. Much gold has been won by sinking shafts and drift mining operations in the rock. There are about 30 shafts in the district, some of which although deep, have not reached the bedrock. Placer mining was carried on in 1931 and 1932, using a small power shovel and a machine to recover the gold from gravel extracted from the rock. The first five feet of gravel above the bedrock, by dry washing methods, is said to have contained \$100,000 worth of gold in places.

In 1930, the Idaho Dredging Company of Boise, Idaho, secured a bond and lease on 1,800 acres of placer ground in the district and began sampling, the object being to dredge the placers. The sampling showed enough gold. After a short time the property and the sampling operation was taken over by the Engineering Company, and further sampling was carried on. The latter company discontinued sampling in May, 1931, and the property reverted to the original owner. The reason for discontinuing the option by the two companies is not stated, but it is probable that it was the erratic distribution of the gold in the low average values.

TELEPHONE CANYON DISTRICT

The Telephone Canyon district is in southwestern Esmeralda County about five miles east of Sodaville. Placer mining is covered in the steep dry canyon below the Belleville. The gold is fine and associated with much black sand. It is said that the gold was derived from the erosion of a network of veins in the quartzite and schist of the vicinity. Placer mining has not proceeded beyond the prospecting stage. In 1931

sunk down to bedrock in the bottom of the canyon, but further development work has been delayed by an excessive flow of water.

NYE COUNTY

BEATTY DISTRICT

It is reported that placer gold has been discovered recently near the town of Beatty in southwestern Nye County, and a number of claims located.

CARRARA DISTRICT

The Carrara district is in the southeastern part of Nye County near Beatty. Placer claims have been located in the district in recent years, but development has not reached beyond the prospecting stage.

CLOVERDALE DISTRICT

The Cloverdale district, also known as the Golden or Republic district, is in the northwestern part of Nye County about 40 miles northwest of Tonopah. Placer gold was discovered in the district in 1906, about four miles east of the Cloverdale ranch. In the years following the discovery small placer operations were conducted, but the total production was not large. On account of the scarcity of water, placer activities have been restricted to dry washing or other types of equipment that require little water.

In 1931, an attempt was made by Los Angeles interests to work the placer on a large scale. The property was sampled by sinking 26 shafts ranging from 20- to 50-feet deep, sunk to bedrock. Machinery of special design was delivered to the property in 1931, but the project was still inoperative in the spring of 1932.

JOHNNIE DISTRICT

The Johnnie district in southeastern Nye County at the northwestern end of the Spring Mountain Range. Lode deposits were discovered in 1903 and the placers in 1921. The placers are distributed over an area of 10 square miles.

The placer area follows the trend of the main lodes, extending from a point two miles north of the Johnnie mine to four miles south of the old Congress mine, a total distance of about 10 miles with an average width of about one mile.

The Johnnie placers have been described by Labbe,¹¹ and, according to his interpretation of the geology, the placers have resulted from the disintegration of quartz veins in the vicinity. The principal placer diggings are in the bottom of the gulches, near the quartz veins. The depth of the gravel varies from 3 to

¹¹Labbe, Charles. The Placers of the Johnnie District, Nevada: Engineering and Mining Journal, vol. 112, pp. 895-896, 1921.

25 feet. Most of the early placer prospecting was done in the vicinity to the veins, with discouraging results.

The best pay gravel is found in the gulches on the surface. The bedrock stratum consists of slightly rounded pebbles with soil or clay. Boulders are also encountered close to the surface. The conditions are essentially the same in all the gulches. The thickness of the pay streak varies little in different places. The thickest pay streak was eight feet in the main Johnnie Gulch at a depth of 25 feet below the surface. The pay channels are small and reunite and their width varies greatly. The upturn of the schist or shale forming natural riffles is the most common feature of the bedrock. The gold is rough and angular, frequently in small fragments of quartz. The gravels are worked by rock washers. In the vicinity are a number of small springs which furnish insufficient water for sluicing operations. Some men haul gravel to the water, while others haul water to the washers. Dry washers have proved effective in saving gold, as the pay gravel is very dry and seldom contains much water. Most of the dry washers used were of the one-man type. The yield of gold by the dry washers is reported to have been from 10 to 90 per cent, depending on the coarseness of the gold.

MANHATTAN DISTRICT

The Manhattan district is in the southern part of the Nevada Range in Nye County, 42 miles by automobile road from Pahrump. The altitude of the district is about 7,000 feet above sea level. The district has an arid climate which is mitigated by the presence of high mountains to the north and east. Precipitation is irregular, and in some years the rainfall for a year may be concentrated largely in a single storm.

The district was discovered in 1905, and placer mining began the following year with dry washing of the rich surface gravel. The district has produced about \$800,000 from the gravel, the bulk of which has been won by drift mining of the gravel. The geology of the Manhattan placers has been described by Ferguson.¹² As interpreted by Ferguson the placer gravels in the district consist of three types; the older bedrock gravels which are remnants of stream erosion, the buried gravel in the gulch, and the recent wash deposited on hillsides and along stream courses. The bulk of the production has been won from gulch gravel. The gulch has been worked by drift mining for about five miles. As with most of the Nevada placers, water is scarce and insufficient in quantity to work the deeper

¹²Ferguson, Henry G. *Geology and Ore Deposits of the Manhattan District, Nevada*; U. S. Geol. Survey Bull. 723, 1924, pp. 117-133.

an extensive scale, such as hydraulicking or dredging. There is, however, a large volume of water flowing through the pay gravels along bedrock which handicapped drift mining to some extent. The depth of the gulch gravel ranges from 20 to 100 feet. In most of the shafts the bedrock pay streak is from two to four feet thick. In general, it has been considered uneconomical to mine bedrock gravel that has a gold content of less than \$2 per cubic yard. Throughout the gulch the gravel is fairly coarse, with an intermixture of clay and sand sufficiently well cemented to stand without a large amount of timber.

The fineness of the gold is about 720 and it is fairly coarse at the upper end of the gulch, the size of the particles diminishing with the distance downstream. The concentrates contain considerable magnetite and barite.

Most of the placer mining has been conducted as small scale drift mining operations. Shafts to bedrock were sunk at intervals of about 300 feet, as it was deemed uneconomical to exceed that distance. Among the best early installations was the one used by Thomas Wilson, the flow sheet of which is shown in Figure 27.

The main feature of the plant was the hoisting equipment, which consisted of an endless chain elevator about 20 inches wide. This raised the gravel from an underground feed bin of 35 cubic

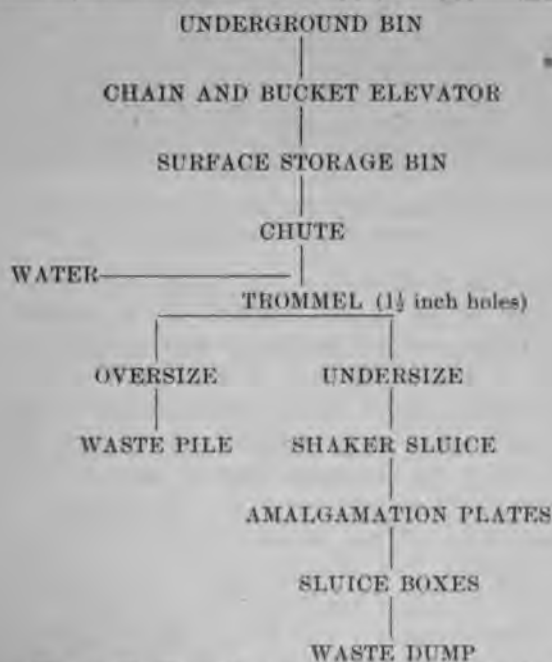


Figure 27. Flow sheet of Manhattan placer plant.

yards capacity placed in bedrock at the bottom of the shaft. The depth of the shaft below the collar was 65 feet. The motor discharged into a 25-cubic-yard capacity storage bin which was built 25 feet above the surface. From the storage bin gravel was sluiced whenever sufficient yardage had accumulated. From the chute of the storage bin the gravel discharged into a revolving screen trommel with 1½-inch diameter holes. The oversize was discharged from the lower end of the trommel into a chute which diverted it to a waste pile. A stream of water played on the trommel to assist in distributing the cemented gravel and to wash the loose clay from the gravel. Directly below the trommel was a shaker sluice, which



Figure 28. Placer gold treatment plant at Queen Placer, Manhattan.
(Waste elevator not shown.)

of a box similar to a sluice box but with deep riffles every two inches of its 12-foot length. By a system of rods the box was rapidly shaken vertically and laterally with a stroke of about three inches lengthwise and an inch up and down. On the lip of the shaker, three small copper plates were placed. Gravel from the shaker sluice passed over the plates, and the fine light gold which did not settle readily between the plates was amalgamated with the quicksilver on the plates. The amalgam from the plates was caught in the riffles below.

Below the plates a line of sluice boxes, all containing riffles, some of which were placed transversely and some longitudinally, extended for some distance. The small percentage of gold which escaped the shaker box and amalgamation plates was

the travel down the sluice boxes. The shaker box caught about 90 per cent of the gold recovered. The power for the elevator, trommel, and shaker box was furnished by a 15-horsepower motor.

In recent years placer operations have been carried on in the Manhattan district by the use of hand-operated dry washing machines, rockers, and small sluices. A placer plant (Figure 28) using special equipment has been erected about one mile southwest of the town of Manhattan to work a hillside deposit of recent wash. The gravel consists largely of angular fragments of schist, with a gold content said to average \$1 per cubic yard. The average depth of the gravel so far worked is about 22 feet. The flow sheet of the placer plant is shown in Figure 29.

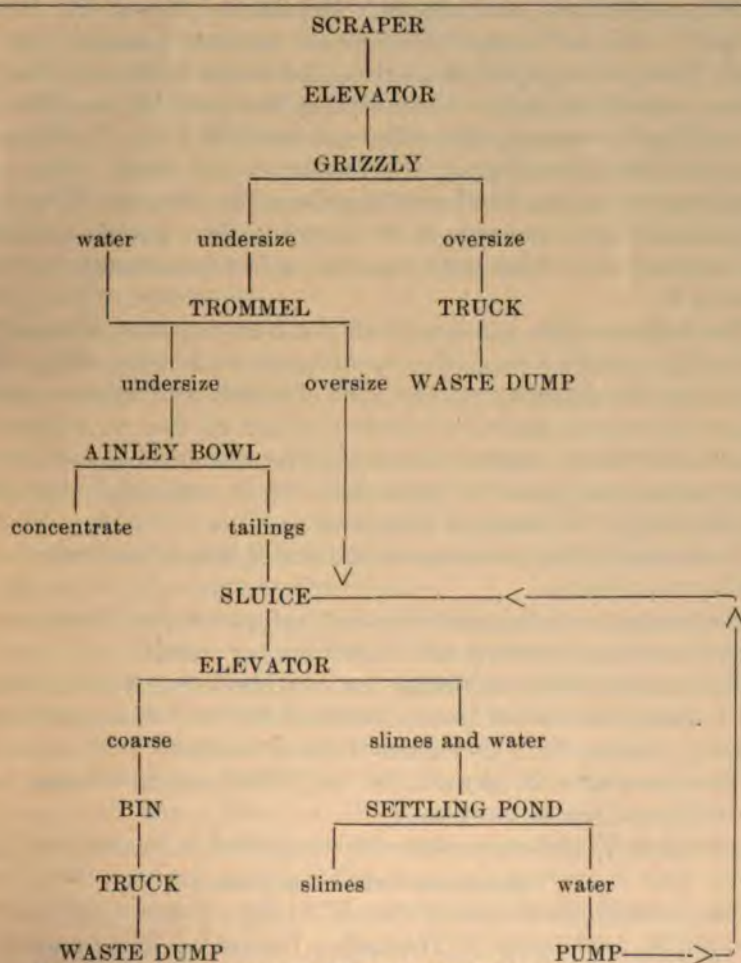


Figure 29. Flow sheet of Queen placer, Manhattan, Nevada.

The gravel is hauled to the elevator by a Macmillan drawn by a caterpillar tractor. In the 1932 operation the average distance of haul was about 75 feet. The material is elevated about 40 feet by an inclined belt and bucket elevator. The elevator discharges on to a rod grizzly with 2-inch openings. Material of an oversized size being diverted by gravity to an automobile. The automobile hauls it several hundred feet to the waste dump. The material from the grizzly passes by gravity to a revolving drum classifier having a 1-inch punched screen on the inside and a 4-inch screen on the outside.

The minus 4-mesh product passes by gravity to a cyclone bowl classifier which operates on the principle of centrifugal force. The bowl is 36 inches in diameter and revolves at a speed of 100 revolutions per minute. The inner side of the bowl is equipped with horizontal riffles which are cast into the bowl. The gravel is fed through a pipe to the bottom of the bowl where centrifugal action concentrates the gold in the center. The tailing is forced up the sides and over the rim. The discharge is made through a plug in the bottom of the bowl. The water requirements of the bowl are 70 gallons per minute. Operators assert that a recovery of 90 per cent of the gold is made in the Ainley bowl. The bowl requires a five horsepower motor to operate it.

The tailings from the bowl and the trommel screen are carried by gravity to a sluice equipped with transverse riffles. The sluice discharges into the boot of a belt and bucket elevator where the coarse gravel is elevated about 20 feet to a bin. Slimes and water overflow from the elevator boot to a pond where the water is reclaimed. It is estimated that 25 per cent of the water is recovered.

From the bin the coarse gravel is loaded into a truck and hauled to the waste dump.

The capacity of the plant is about 16 yards per hour. The total water requirements are 70 gallons per minute.

The water is obtained from the Amalgamated Mining Company shaft where it is bailed from a depth of 500 feet with a 2-inch bailer. A two- and three-inch pipe line about two miles long carries the water by gravity to the 23,000 gallon storage tank on a hill near the placer plant.

A total of 20 motor horsepower is required to operate the plant.

ROUND MOUNTAIN DISTRICT

The Round Mountain district is in Nye County, 6 miles from an automobile road north of Tonopah. Tonopah is the nearest road point and supply center. The district is served by the

automobile stage from Tonopah. The town of Round Mountain has an elevation of about 6,300 feet above sea level.

The principal lode and placer deposits were discovered in 1906. The total placer production to date is \$1,295,920, which was obtained from 1,383,400 cubic yards of gravel; an average of 94 cents per cubic yard. Of this amount, the lessees produced, from 1906 to 1915, \$442,940 from 272,240 cubic yards of gravel; an average of \$1.63 per cubic yard. Hydraulic mining by the company produced the remainder.

The mountain from which the camp derives its name rises several hundred feet above the surrounding terrain. The principal lode and placer deposits are on Round Mountain. The more productive veins are the Los Gazabo, Keane, and Placer. From the erosion of these veins, and the stringer zone lying between them, the main placer deposits have been derived.

The main placer deposit is on the south slope of Round Mountain. It is of the residual type, none of the gold having traveled more than several hundred feet from its source. The depth of the gravel varies from a few feet up to 50 feet, and it consists of 15 to 20 per cent of large angular boulders, and the remainder sand and gravel. The bedrock is uneven, so that considerable gold is retained in the crevices which necessitates considerable hand work to recover it.

The gold averages about 635 fine, being alloyed with silver. Most of the gold is coarse. The proportion of gold to quicksilver in the amalgam recovered in sluicing operations is about 60 per cent.

The first placer mining in the district was in 1906 with dry washing machines. A description of the early-day operations with dry washers has been given by Packard.¹³ The machines used in dry washing at that time are essentially the same as those in general use throughout the State.

In operating these dry washers the large rocks were picked out by hand and thrown to one side. The gravel was then thrown against a screen having one-inch openings. The undersize was shoveled upon the dry washer screen which had one-quarter-inch openings. The oversize was discharged to waste over a piece of sheet iron which projected two feet beyond the lower end of the machine, and the undersize diverted to the head end of the machine where it was fed upon a frame covered with coarse heavy cotton cloth, across which riffles were placed about four inches apart. This frame formed the upper side of a bellows operated

¹³Packard, George A. Round Mountain Camp, Nevada: Engineering and Mining Journal, vol. 83, p. 151, 1907.

by turning a crank. The puffs of air through the cloth the gravel and, aided by the slope of the frame, discharge the lower end.

Two men were required to operate a single machine. One turned the crank which actuated the bellows and the other shoveled the gravel on to the machine. After about 1000 fuls had passed over the machine, the frame was replaced by another. The concentrate consisting of sand, gold and gravel retained by the riffles was placed in a tub. Later the accumulated concentrates were passed over the machine a second time and the tailings, which carried about \$60 in gold per ton, sacked for shipment. The concentrate from the second washing was cleaned in a gold pan, and the sand removed by a magnet. One machine with two men working about 10½ hours per day handled about 17 tons of gravel. The depth of the gravel worked ranged from one to six feet. A dry washer made a recovery of about 70 per cent of the gold. No definite figures are available as to the gold content of the gravel, but it is believed that the material handled by the first washers ranged between \$2 and \$10 per cubic yard. Inasmuch as the dry washing operations were confined to gravel in gravel pits, basins, and other natural concentration areas, the yields of gold per cubic yard are not unreasonable. Later, the gravel was washed below the site of the dry washing operations was hydraulicked by lessees, who treated 100,000 cubic yards which gave an average of \$2 per cubic yard.

From 1906 to 1915 all placer mining was done by hydraulic methods. In 1907, the Round Mountain Hydraulic Company was organized and water piped from Jefferson and Shoshone Creeks to the mine. The line was 12 to 15 inches in diameter and several miles long.

In 1914, the Round Mountain Mining Company, the successor of the Nevada Porphyry Gold Mines, Inc., began the operation of a pipe line from Jett Canyon to the placer deposits. Operations were begun on July 13, 1915, and continued until September 3, when the flow of water in Jett Creek had diminished to such an extent that operations for the year were closed. In this first season, 18,150 cubic yards of gravel were washed, which yielded \$36,414 in bullion. The operating cost was \$11,058, leaving a net profit of \$25,356. Two dollars per cubic yard of gravel recovered, and the total cost per yard was 61 cents.

As the water supply from Jett Canyon was inadequate for hydraulicking on such a large scale, the water rights of the Slaughterhouse, and Shoshone Canyons were purchased.

Round Mountain Mining Company from the Round Mountain Power and Water Company. This enabled the company to handle a much greater yardage by lengthening the placer season and reducing operating costs. Placer operations have been conducted every year since, the length of the operating season depending on the amount of water available.

The pipe line from Jett Canyon is 45,336 feet long. The first section, beginning at the intake in Jett Canyon, consists of 14,000 feet of riveted steel asphaltum dipped pipe, ranging from 30 inches to 15 inches in diameter. The second section consists of 28,000 feet of lap welded steel pipe from $\frac{1}{4}$ to $\frac{5}{16}$ -inch thick. This lap-welded pipe was necessary because the pipe line in the floor of the valley forms an inverted siphon 1,142 feet lower than the intake. The maximum static head on the pipe line in the valley floor is equivalent to a pressure of 495 pounds per square inch. The third section of the pipe line is 3,336 feet long and consists of riveted steel asphaltum dipped pipe 15 inches in diameter. The entire line is buried 42 inches deep for protection against freezing during winter. Of the riveted steel pipe, 7,550 feet is equipped with slip joints where the pressure is light; the remainder is plain end with bolted steel forged couplings. The pipe line traverses Jett Canyon for 10,000 feet and then continues in a straight line across the valley to the mine. It was designed with a safety factor of five, and is equipped with drains, air and pressure relief valves. Exclusive of the Jett Canyon water right, which cost \$28,410, the cost of the pipe line was \$150,557. The difference in elevation between the intake of the pipe line and the placer banks is 650 feet.

After the high water season had passed in 1916 and 1917, it was the practice to close the valve at the end of the Jett Creek line and for several hours allow the water to back up in the line, after which the valve was opened and sufficient water obtained for short periods of hydraulicking. Despite the safety factor on the line, this did not seem very good practice, so in the latter part of 1917 an earth dam was built above the intake in Jett Canyon. This dam cost \$3,000, and permitted the impounding of sufficient water to provide a full head for a large monitor for eight hours. The expense of the other shifts was thereby eliminated.

In order to provide for more continuous operations at Round Mountain it was necessary to provide additional impounding facilities. Until 1920 the pipe lines from Jett and Jefferson Canyons were connected direct to the giants. The additional impounding facilities were provided in 1921 by building a small

reinforced concrete dam in a gulch about one mile from the placer banks. This dam is 22 feet high, in the center of the gulch and impounds sufficient water from the two pipe lines to permit continuous operation of the monitor for seven hours. The difference in elevation between this dam and the placer banks is 350 feet.

The first sluice, built in 1915, was 2 feet wide, 2 feet deep, and set at different grades. This proved to be too small and was abandoned above bedrock. The site of the new sluice was determined by drilling an appropriate number of holes to bedrock. The new sluice, built in 1921, is 3 feet wide, 3 feet deep, and 10 feet long, with a uniform grade of 4 inches per 12 feet. The capacity and better efficiency of the new sluice reduced the cost per cubic yard of moving the gravel. It is constructed of plank with 2 by 4-inch lining boards. The supporting side members are 4 by 4-inch timbers with 1 to 6-inch cross-bracing. The sides are of rough lumber, but the bottom is built of plank 18 inches wide, surfaced on four sides in order to prevent the loss of quicksilver and finer particles of gold.

The present sluice has outlived its usefulness, and at the end of the placer season of 1932 it is proposed to construct a new one to reach another part of the placer area which has been previously sampled. It is estimated that this sluice will be in use for 15 years. It will be the same size as the one now in use.

In early hydraulicking operations it was the practice to use a giant at the lower end of the sluice to pipe away the material as they accumulated. As water is the controlling factor in the amount of material handled, a scheme was devised to eliminate the use of the tailings giant was eliminated. A system of tailing races was installed at the lower end of the sluice, which permitted diverting the flow of water and gravel to one branch to another. One branch was extended which permitted the use of all the water for hydraulicking.

The first riffles used at the Round Mountain placer mine were of pine blocks about six inches in length set in the bottom of the sluice in rows. Each row was separated by a riffle stick of 4-inch board. With this arrangement of the riffles a sluice 50 to 100 feet long would be torn out by the angular riffles causing considerable delay and undoubtedly entailing the loss of gold. This unsatisfactory riffle was replaced by a system of transverse and longitudinal types of riffles are common.

The transverse type of riffle is considered the best for

being normal to the direction of flow of the material, but at the same time it offers considerable resistance to the flow of gravel over it. The pole or longitudinal type riffle permits a free flow, but is not as effective in saving the gold, because the gravel and rocks pack between the poles and permit the escape of some of the finer particles of gold. To utilize the best features of both types of riffles, 3 by 4-inch timber crossties are placed in the bottom of the sluice at intervals of 4 to 6 feet. Upon them are laid 7 parallel lines of 25-pound rails, which are fastened into the sluice with wooden blocks. The top of the blocks are set level with the top of the rails. These blocks serve the purpose of riffles, without greatly retarding the flow of material through the sluice. Along the upper 3,500 feet of the sluice the rails are placed with the flat side down, but inverted in the lower 1,500 feet to increase the sliding motion of the large boulders.

The crossties beneath the rails act as cross riffles. As the rails are held suspended above the bottom by the crossties, a certain amount of vibration is set up by the rocks passing over them, which causes the gold to settle to the bottom. At intervals of about 100 feet cast-iron blocks reaching to the top of the rails are fastened to 3 by 10-inch cross timbers. These blocks divide the sluice into sections, so that in case a rail is dislodged only one section will be affected, and repairs made quickly. However, since this type of riffle has been in use no trouble has been experienced on account of the rails becoming loose.

One advantage of the rail riffle is that the greater part of the wear is at the center of the sluice. The center rails allow the hydraulicking of about 150,000 cubic yards of material before they show any appreciable wear. When the center rails become worn, they are moved to the outside of the sluice and the outside rails moved to the center. In this way the wear on the rails is equalized and they all wear out about the same time.

In the placer operations at Round Mountain, the handling of the rocks and boulders too big to be moved by the giants has been a problem. Various methods have been tried; in one method the large rocks were blockholed and blasted, and the smaller ones broken by hand sledges. An attempt was made to run all the rocks through the sluice except the larger ones, which were broken by blasting, but the proportion of rocks soon became too great and this method was abandoned.

The present practice is to blockhole the larger rocks and remove them along with others which can be conveniently handled by either of two ways: (1) By rock cars which are hoisted out of

the placer pit on a trestle and automatically dump boom derrick. In the first method, specially constructed cars built on standard 30-inch gauge mine trucks are used. The cars are wheeled from the pit on 12-pound rails which are connected by switches to the rails leading to the trestle track. Figure 30 shows a loaded car ready to be hauled out of the pit. The boom derrick, a flat, heavily constructed timber platform supported by a derrick, a flat, heavily constructed timber platform reinforced with iron is employed. Chains are fastened to



Figure 30. Car for handling boulders at Round Mountain placer.

of the platform to form a sling. A three-quarter-inch cable is fastened to the sling passes to the derrick and to an anchor. The pole of the derrick is set at a slight angle from the vertical so that the boom automatically swings out of the pit. When stationed at the dump pile to unhook two of the chains, starting the hoist the platform is emptied of the rock.

The empty platform is then swung back into the pit. Three platforms are used so that two are being loaded while the third is in transit.

In blockholing the larger boulders, standard jackhammer machines are used. The depth of the holes drilled varies with the size of the boulders and ranges between 6 and 12 inches. The explosive charge is from $\frac{1}{4}$ to $1\frac{1}{2}$ sticks of 40 per cent gelatine dynamite in each hole.

The amount of water available at the placer banks is approximately 400 miners' inches. Two small or one large giant is used in each of the two pits, which are operated at the same time in order to permit cleaning up the sluices in one pit while hydraulic operations are going on in the other. Figure 31 shows a 7-inch



Figure 31. Hydraulic giant in operation at Round Mountain placer.

giant in operation. The lines are so arranged as to permit the use of all the water in either pit, or prorating it as the occasion demands through the use of a system of by-passes and valves.

The amount of material moved with 400 inches of water under a head of 350 feet varies considerably, and depends on the height of the bank and the amount of rocks and cemented material. The range is from 32 to 110 cubic yards per hour.

On account of the angular rocks, the giants are not placed in the usual position, directly opposite the bank to be hydraulicked, but are generally set at an angle to the banks, as the angular rocks do not pass readily into the sluice and the force of the water is generally needed behind the material rather than in front of it.

It is also necessary for the giant operators to use care in not putting too much soil without a proper proportion of rocks. If a pile of rocks accumulates and, without the water having the proper density and buoyance due to the proper admixture of rocks, an undue proportion of rocks have to be removed by the methods previously described. Also, care must be exercised in filling the sluice because if the water is allowed to get too low the gravel will settle and choke the sluiceway.

At times a considerable proportion of cemented gravel in the placer banks makes blasting necessary. The practice is to drill 5-inch holes with a Star drilling rig. These holes are drilled to bedrock, about 50 feet apart, parallel to and 25 feet from the edge of the bank. Following are the details in one instance of this practice: Four of the holes were drilled to an average depth of 46 feet and each hole was sprung with 15 pounds of high strength gelatine dynamite. After springing, each hole was loaded with 175 pounds of Judson powder and detonated. This resulted in thoroughly shaking and loosening 12,000 cubic yards or about 17 yards of gravel per pound of powder. The cost of these holes, including setting up the drill, moving it from place to place, to hole, sharpening drill bits, explosives and labor, was about 41½ cents per cubic yard.

The bedrock is very uneven and rough. After it has been cleaned as much as possible with the monitors, it is left to dry, and then cleaned by hand, using specially constructed tools and whisk brooms for removing the gold from the crevices.

The cost of bedrock cleaning per cubic yard of material removed varies with the height of the bank hydraulicked, the nature of the bedrock and several other factors. In one instance, where 128,000 cubic yards of gravel were sluiced, the cost of bedrock cleaning was 15½ per cent of the total cost of the operations. During this same year 72.7 per cent of the gold recovered came from the semimonthly clean-ups, 11 per cent from the bedrock cleaning, 9 per cent from the lower reaches of the sluice and 7.3 per cent from milling residual material in the sluice.

At the end of each worthwhile season, the sluice is cleaned for a distance of several hundred feet beyond the point where the semimonthly clean-ups extend, and, in the fall, at the end of the placer season, all rails in the sluice are removed and the material remaining in the sluice allowed to dry, after which it is hauled to the mill and treated the same as ore. This material has a value of about \$60 per ton.

Quicksilver is added from time to time while sluicing is in progress. The amount is dependent upon the yardage and the value per cubic yard as determined by panning tests. Clean-ups are made semimonthly by running down about 200 feet of the upper end of the sluice, removing the lining boards, blocks, rails, and crossties, while a small amount of water is flowing through the sluice. The blocks, rails, and crossties are thoroughly scrubbed with brooms to remove any particles of adhering gold or amalgam. Additional quicksilver is then added and the flow of water in the sluice increased, causing the material to move slowly down the sluice. As this goes on the rocks are forked out with eight-tine sluice forks. The gold, or amalgam, moves down the sluice behind the lighter material and is scooped up, placed in buckets and taken to the mill for grinding in a clean-up pan, as much of the gold is associated with quartz and other vein material. The gold is then amalgamated, retorted, and melted. The gold is sent by registered mail to the American Smelting & Refining Company, at Selby, California. The bullion is insured for its full value from the time it is deposited in the post office at Round Mountain. This method has proved cheaper than transporting to the railroad and shipping by express.

Yardage measurements are made twice a month while operations are in progress. Preparatory to mining, the placer banks are drilled and sampled. In sampling, an area is surveyed and divided into blocks one hundred feet square and holes are drilled, or pits sunk at each corner of a square. Samples of the drill holes or test pits cover vertical intervals of 10 feet. Each sample contains from 60 to 100 pounds of material. The samples are thoroughly dried, weighed and passed through a small sluice box about 15 feet long, and 6 inches wide, using the Hungarian type of riffle with quicksilver in the sluice. After each sample is sluiced, the box is cleaned up, the recovered amalgam retorted and the gold proportioned against the weight of the sample.

In computing yardage, each square is divided into four equilateral triangles and a separate computation made for each triangle. This method gives a better safety factor than would be obtained by using the four holes at the corner of the 100-foot squares.

An average of about 20 men are employed during the placer season.

UNION DISTRICT

The Union district, also known as the Berlin or Ione district, is in northwestern Nye County on the west slope of the Shoshone

Range. The district was discovered in 1863 and the town established and made the county seat of Nye County. The placer production of the district has been unimportant.

In 1932, an attempt was being made to work a placer one mile southwest of Ione. Here, the surface débris of one or two feet is said to average over \$1 per cubic yard. Equipment for mining and treating this placer material consisted of two drag line scrapers, a specially designed placer machine, and a power plant. The placer machine is shown in Figure 32. Water required for washing the placer material was piped to the plant by gravity flow from Ione.

The material was transported to the machine by a drag line scraper of about one-half cubic yard capacity. The material was brought up an inclined runway and dumped over a grizzly, from which the undersize was screened. The fines contained



Figure 32. Placer gold machine of special design at Ione.

The material is treated on a series of small shaking sluices from which the gold and black sands are discharged at one end. The material from the machine, along with the grizzly oversize and material too coarse to pass through the screens, are discharged at one side of the machine, where they are picked up by a drag line scraper and piled some distance away. The entire cost of the plant was in the neighborhood of \$15,000.

The plant had not been in operation long enough to determine its capacity or efficiency at the time of the visit.

**PERSHING COUNTY
PLACERITES DISTRICT**

The Placerites district is about 15 miles southeast of Sulphur and 47 miles north of Lovelock, in northeast Pershing County. The placers occur in low hills in the vicinity of the corner of T. 32 N., R. 29 E. (Figure 33). J. T. Reid of Lovelock states that placer gold was discovered in the district in the fifties, but because of lack of water very little placering was done in the early days. In the nineties some placer activity was carried on; the gravel being hauled to a spring. The total production of the district has been in the neighborhood of \$10,000. In 1928, C. J. and E. G. Stratton worked eight months in the district and recovered \$5,000 from the placers. The gravel ranged from 25 cents to \$5 per cubic yard.

In recent years about 4,000 acres were acquired by a stock



Figure 33. Placer mining in the Placerites District.

company which attempted to work the gravels on a large scale. A reservoir averaging about 1,000 feet long, 35 feet deep, and 35 feet wide was excavated in an adjacent valley (Figure 34). The water rose in the reservoir to within 20 feet from the surface and it was thought the water would be sufficient for profitable large scale operations. From the reservoir the water was pumped to a tank above the placer area and a drag line scraper was installed. The gravel was screened in a trommel and the undersize sluiced. The amount of water available in the reservoir was inadequate, and in 1932 a gravity pipe line was laid from Cow Springs, six

miles distant. In addition, the drag line scraper was replaced by a gasoline power shovel. Due largely to lack of capital, operation has not been commercially successful.

The bedrock in the greater part of the placer area is composed of sedimentaries, principally slates and shales. The gold occurs mainly at the heads of the shallow ravines, and probably has not traveled far. The gravel varies in depth from 1 to 3 feet, and consists of small size material.

RABBIT HOLE DISTRICT

The Rabbit Hole Spring placer area is north and west of Rabbit Hole Spring and about five miles northeast of Placerville.

Placer mining has been carried on in the district in recent years



Figure 34. Water reservoir and pumping plant for placer operations, Placerites District.

by small scale hand methods. In one instance the gravel was hauled a distance of four miles to Rabbit Hole Spring for processing in a rocker. The gold bearing gravels occur in the sides of a number of small ravines. The best values are found near the heads of ravines, also on slopes above the ravines. The average depth of the gravels worked is about three feet, resting on a false clay bedrock. Both coarse and finely divided gold are found, and it is associated with a considerable amount of sand. The gravel is rough and angular, rather small, but few boulders, which do not usually exceed 14 inches in diameter.

In the autumn of 1932 a company began operations on

scale. A graded road three and one-half miles long was built from the placer banks to Rabbit Hole Spring, over which a fleet of five-motor trucks convey pay gravel to a washing plant. The plant set-up and treatment is as follows: Gravel is dumped from the trucks into a hopper, from which it feeds on to a Barber-Green belt conveyor, which delivers it into a revolving trommel, 12' long, 48" in diameter, covered with $\frac{1}{4}$ -inch mesh screen; 50 gallons of water per minute washes the gravel through the trommel. From the trommel the coarse goes to waste and the fines are washed into two power-driven rocking sluice boxes, one of which is 16' long, 4' wide and the other 12' long and 3' wide, each set on a grade of 3" per foot, and fitted with transverse riffles. Below each rocking box are short stationary sluice boxes, set on a grade of $1\frac{1}{2}$ " per foot, 16' long and 19" wide, in the bottom of which are amalgamated copper plates extending entirely through the boxes. At the lower end is an amalgam trap. Above the upper copper plate is a 16-mesh screen to screen out and carry away the coarse sand. After passing over the screen, the coarse sand is washed on out of the box over a steel plate superimposed just above the lower amalgamated plate. Water at the rate of 50 gallons per minute is supplied by two centrifugal pumps for all operations, and the power for the plant is developed by a 28 horsepower gas engine. The owners state that the initial operation in October, 1932, yielded an average of \$2 per yard, and that the plant can handle from 100 to 200 yards per day. Fifteen men are employed at the mine and washing plant.

During the summer of 1932, 100 sampling pits were sunk on the property, ranging in depth from 3 to 15 feet, the average being 6 feet.

ROCHESTER DISTRICT

The Rochester district is in central Pershing County about 22 miles northeast of Lovelock.

The placer deposits were discovered in the early sixties by men from Rochester, New York. The district attained considerable prominence when important silver veins were discovered by Joseph Nenzel in 1911.

The placers have been worked intermittently, and according to report it was the practice for a number of prospectors to procure annual "grub stakes" from the placer deposits in Rochester Canyon. The early placer workings in this canyon have been covered with large accumulations of cyanide mill tailings. The auriferous gravels are in places from 50 to 100 feet thick. The bedrock is quartzite, and the values are said to occur in the

gravel from surface to bedrock. The gold is rough line and has a value of about \$16.50 per ounce. Much is associated with the gold.

In Limerick Canyon, about one mile north of Rochester, placer gold deposits have been worked in former days. Placer gold was discovered in the east end of Limerick where the gravel occurs in a low sagebrush covered location. This location was profitably and thoroughly worked by dry washers. In one place where the gravel averaged 12 feet in depth, for a while two men with a rocker took \$100 per day. The pay gravel was from 12 to 15 inches in an old channel above bedrock. The rich pay was in place with from 4 to 10 feet of overburden. Other groups of miners worked in this area with hand operated dry washers. Dry washers were successful, as the gravel was dry and quite coarse.

From 1914 to 1917, inclusive, W. W. Walker and E. J. of Lovelock sank a series of shafts from 15 to 20 feet to the upper end of Limerick Basin and mined over 200,000 cubic yards of the channel by drift mining. Pay gravel on bedrock was found to have averaged \$35 per cubic yard. Water being scarce in the vicinity, the gravel was either hauled six miles to a spring or water hauled to the diggings. The gold was recovered by dry washing. Over \$40 per day was recovered with a rocker in one month, and a few rich patches of gravel were found worth \$5 per pan. From 1914 to 1917 the operation netted \$18,000.

Near the west end of Limerick Basin, Andrew J. earned a living for a number of years by working claims. In 1931 the Limerick Canyon Mining Company installed a small pilot washing plant with a capacity of six yards per hour. The gravel was first handled by a drag line scraper and then by a small power shovel. Water was piped two and one-half miles to the plant. The company was forced to curtail operations because of water shortage.

In 1931 placer gold was discovered in Gold Springs at the mouth of Rochester Canyon. Here the placer deposit is a lightly cemented gravel lying on a false bedrock of volcanic ash. In 1931 and 1932 the gravel deposits were expected and the gold recovered by dry washing. Small quantities were found, the largest of which had a value of \$400. The gravel is from four to eight feet deep. It is contemplated to obtain water for working on a larger scale by pumping water from the Rochester silver mine shafts or by sinking wells in the

As pointed out by Schrader,¹⁴ the Limerick Canyon placers are of special geological interest for they may indicate the course of an ancient stream channel which may have crossed the range by way of Spring Valley Pass. In Walker Canyon and American Canyon on the east side of the range, well-washed gravels containing granite pebbles occur, although granite is not present in the neighboring rocks. In Limerick Canyon and Basin the gravels are a heterogenous mixture of rough and subangular rocks and well-rounded pebbles, the latter probably having been derived from the erosion of an ancient stream channel near the crest of the range.

ROSEBUD DISTRICT

The Rosebud placer area is in northern Pershing County, about 12 miles south of Sulphur, a station on the Western Pacific Railroad. Placer gold was discovered in the early days and several thousand dollars in gold recovered by dry washing. The placers have been worked for a number of years by the Delavaga brothers, who stated that they had recovered about \$3,000 in gold from all operations.

In 1931 a stock company, called the Associated Royalty Mining Company was organized and a total of 4,160 acres of potential placer ground acquired. It was proposed to bring in water from several springs in the vicinity for working the gravels.

In 1931 a shaft was sunk to a depth of 40 feet in a gulch tributary to Rosebud Canyon, with the expectation of finding water in order to dispense with a two-mile water haul from Rosebud Springs. Water was encountered, and in addition it is reported that clean gravel yielding \$2 per cubic yard was discovered. Trenching in the ravine showed some coarse gold near the surface.

SACRAMENTO CANYON DISTRICT

Sacramento Canyon is located on the northwest flank of the Humboldt Range in central Pershing County, about five miles east of Oreana.

Placer gold was discovered in this canyon in 1912, and a small amount of prospecting was done. Placer operations have not been conducted in the district in recent years.

SAWTOOTH DISTRICT

The Sawtooth or Mandalay district is in northern Pershing County near the Humboldt County boundary line. It is about 50 miles north of Lovelock and 25 miles east of Sulphur.

Placer gold was discovered in the district in the summer of 1931 as a result of prospecting stimulated by the development

¹⁴Schrader, F. C. The Rochester Mining District, Nevada: U. S. Geol. Survey Bull. 580, pp. 371-372, 1913.

of the gold veins at Scossa, which is about 10 miles south after the discovery of the placer gold, four groups were working the gravel with dry washers with very good results. Before the summer of 1931, 35 men were working the gravel with dry washing equipment and a large number of claims had been staked. It is reported that some of the gold recovered from \$5 to \$35 per day by dry washing. Work was continued in 1932, and in addition a company was organized to work the gravels on a larger scale. The Oregon-Nevada Mining Company installed a Rose concentrator which had a capacity of 100 tons per day. The concentrator was fed by a drag line scraper. About sixteen men were employed. Water for the concentrator was pumped from Mandalay Spring in the district.

The gravel is rough and angular, with a small percentage of large boulders. Much of the placer material is composed of fragments of schist. The gold is coarse and rough and a good recovery can be made by dry wash methods. The gold is distributed throughout the gravel, with but little concentration on the bedrock. The gravels are from one foot up to 12 feet deep. In places considerable barren overburden is present. The depth of the pay gravel is about three feet. One dry washer reported a recovery of \$2 to \$10 per cubic yard of gravel. In the summer of 1932. Nuggets up to \$4.50 in value have been recovered.

SIERRA DISTRICT

The Sierra district, also known as the Dun Glen, Sunshine, and Chaffee districts, is about 40 miles north of Lovelock and 12 miles east of Mill City, the latter at the Southern Pacific Railroad.

The first lode discovery in the district was made in 1880. The placers a short time after. The placer deposits cover a wide area and include deposits in Auburn, Barber, Rock Hill, Dun Glen, and Spaulding Canyons. The total production of placer gold in the district has been about \$4,000,000, from Barber, Wright, Auburn, and Rock Hill Canyons. A part of the production was made in the eighties and nineties by Chinese placer miners.

Some exploratory work was done in Dun Glen Canyon in 1932 by tunneling and sinking shafts. The Dun Glen Canyon is a length of about 4½ miles, with a maximum width of about 1,000 feet and an average width of about 200 feet. A number of shafts have been sunk in the canyon in past years for testing. The depth of these shafts to bedrock varies from 18 to 25 feet. It is reported that from 5 to 6 feet of the gravel directly

rock will average between \$2 and \$3 per cubic yard. Working the gravels by drifting has been handicapped by the large quantities of water encountered near bedrock. The gold is coarse. In Barber Canyon a company organized in Los Angeles acquired about 1,000 acres of placer ground in 1931. The company installed specially designed land dredge for treating the gravels. The dredge had a capacity of 100 cubic yards per day. Gravel was excavated by a power shovel.

Considerable sampling was done by drilling in the canyon prior to the installation of the equipment, and the results of this work gave values varying from 60 cents to \$1.75 per cubic yard. Water concentration is obtained from an old shaft in the vicinity.

In Spaulding Canyon, in 1932, about six groups of men were employed in small scale placer mining along a two-mile length of the canyon. All were reported as making wages.

In 1930 to 1932 a number of men were dry washing the gravels in Antelope Canyon about four miles west of Humboldt. Here the gold occurs in pockets, and several nuggets worth \$7.50 each were found. In 1930 two men are reported to have recovered 1,000 in gold with a hand operated dry washer.

SOUTH AMERICAN CANYON

South American Canyon is about one mile south of the American Canyon in the Rochester mining district. This canyon was worked intensively by Chinese for many years; the last survivor of the former colony of Chinese placer miners having died about 20 years ago. Judging from the extent of the placer workings in the canyon a large amount of gold was recovered. About halfway up the canyon from Buena Vista Valley is a bowl-shaped depression about 1,500 feet wide which formed a natural concentration area for placer gold. This basin, or depression, is barred by numerous shafts and tailings piles, and none of the shafts are over 15 feet deep. The gravels are subangular and contain no large boulders. The gold was recovered by the Chinese by panning and rocking. Water was obtained from several springs in the lower part of the canyon. The best ground in the canyon has undoubtedly been worked by the Chinese, and recent attempts to find pay gravels have not been encouraging.

SPRING VALLEY DISTRICT

The Spring Valley district is on the east flank of the Humboldt Range in central Pershing County, about 30 miles northeast of Lovelock. Although lode mines in the district were active as long ago as 1868, placer mining operations did not begin until 1931. The Spring Valley and American Canyon placer areas have

attained the largest production of placer gold in the State. Estimates of production vary from \$10,000,000 to \$20,000,000. In the first years following their discovery the placer mines were worked by Americans, but were later taken over by Chinese. The Chinese made the bulk of the production. According to Locke,¹ in the early nineties hundreds of Chinese were working the placer mines in American Canyon. Ample evidence of the intense activity that prevailed remains in the hundreds of shallow shafts and piles of gravel spread over a length of two miles along the canyon. After working a short time the Americans leased the placer mines to a Chinese placer operator on a royalty basis. This operator brought in hundreds of his countrymen to whom he subdivided the ground in blocks of 20 feet square. Each lessee sank a shaft to the pay streak and mined out the pay ground above the shaft within the limits of his lease. Hundreds of piles of gravel attest the energy with which the work was conducted. Locke stated that each block of 400 square feet produced an average of \$1,500 to \$3,000 in gold dust and nuggets. As the miners were secretive as to the amounts of gold taken out, and the source of this gold never found its way to the mints in this State, the aggregate amount of gold recovered will never be known with any degree of accuracy.

The source of the gold in American Canyon has not been definitely traced, but it is believed to have originated in the erosion of porphyry hills through which the canyon was cut by the action of water. In working the gravels downstream, the bedrock is porphyry for a distance and then changed to limestone. The pay streak was found on a false bedrock of clay generally 10 to 20 feet from the surface, being shallower at the upper end of the diggings and increasing in depth at the lower end. A shaft sunk through to limestone bedrock at the lower part of the diggings, but the pay streak still retained its position at 10 to 20 feet from the surface, and little or no gold was found below the false bedrock and none on the limestone.

Spring Valley, in addition to the neighboring Dry Lake, and American Canyons, was also the scene of small scale placer mining operations by Chinese in the early years. In 1910 the Nevada Mines Company installed a dredge which worked in the river until 1914 with good results. The dredge worked in gravels averaged from 22 to 30 cents per cubic yard, and they consisted of stream and bench gravels which varied in depth from 10 to 30 feet. The gold occurred in the gravels from the surface

¹Locke, Ernest G. *Reawakening of an Old Placer Camp*: Min. & Geol. vol. 107, p. 373, 1913.

The alluvium contained many large boulders of granite and rhyolite which interfered considerably with dredging operations. The bedrock was a hard blue limestone. The gold was coarse, and nuggets worth from \$3 to \$5 were common. The gold had a fineness of about 700.

One operating disadvantage in the dredge operation was the scarcity of water, which had to be piped from Indian Creek, five miles distant, and considerable difficulty was met in keeping the dredge afloat because of the steepness of the canyon and the underground workings, which threatened to drain the dredge and.

The dredge was of wood construction and the digging ladder was of the open connected link type, which is best adapted to ground containing large boulders. The capacity of the dredge was 2,000 cubic yards per day. After screening and washing in trommel the undersize passed on to tables sloping 1 inch in 15 which were equipped with angle iron riffles. There were 40 linear feet of tables 6 feet in width, and in addition the gold saving equipment consisted of 32 feet of sluices and riffles.

The stacker consisted of a continuous chain of buckets closely connected and driven by a rope transmission from the main drive. The power for operating the dredge was furnished by four diesel burning engines having a sea level rating of 100, 55, 30 and 8 horsepower, respectively. The altitude at which the dredge operated was 5,000 feet above sea level, so that the total effective horsepower was only 81 per cent of the sea level rating, or about 6 horsepower. The 8 horsepower engine drove the dynamo for lighting and a small pump for priming, the 30 horsepower engine drove the winch, the 55 horsepower the double 10-inch centrifugal pump, and the 100 horsepower engine operated the digging ladder, screen and stacker. Head and side lines were used instead of spuds for holding the dredge in position.

In recent years placer activity has been resumed on a small scale in the district, but no large production of gold has been made since the early day operations.

UNIONVILLE DISTRICT

The Unionville or Buena Vista district is on the east slope of the Humboldt Range in central Pershing County, about 30 miles northeast of Lovelock.

Placer gold was discovered early in Buena Vista Canyon, in which the old town of Unionville is situated. Placer gold was also found in the neighboring canyon, where it is reported to have been worked in the late forties, probably by the Spaniards.

Above the town of Unionville a new placer discovery in 1931. Here the gravel is from 6 to 10 feet deep with streak on bedrock from 2 to 3 feet thick. In 1932, several scale placer operations were being carried on in the district and the earnings were reported as high as \$10 per day. Operations are handicapped by the scarcity of water.

WEAVER CANYON

Weaver Canyon is one mile south of the mining camp of Rochester, and lies between the mining camps of Rochester and Packard. The canyon is about two miles long and has a north-south course. It has been prospected and a small production of gravel by hand methods in early days. The gravels are and contain some large boulders. The ores of the Colligan and other mines at the head of the Canyon contained gold, and thought the placer gold was derived from these sources suggested that this canyon may be worthy of further investigation for profitable pockets in the alluvium.

WASHOE COUNTY

LITTLE VALLEY

Little Valley, in which the profitable placers were found in the southwestern corner of Washoe County. It occupies a trough four miles long having a north and south axis, and is on the eastern slope of the Sierras at an elevation of 6,500 feet. The valley was formed by a fault parallel to the axis of the Sierra Nevada range.

Although Little Valley adjoins the Voltaire District of Washoe County on the south, it is wholly in Washoe County and does not form a part of any organized mining district. The placers were worked in the early days, and the total yield of placer gold is said to be in the neighborhood of \$100,000.

Aside from their economic importance, the placer deposits are interesting from a geological viewpoint, as they occur in an ancient tertiary river channel. This ancient channel has been traced from a point near Incline on Lake Tahoe to a point a short distance east of the south end of Washoe Lake. In places the river gravels are overlain with rhyolite and andesite flows. The gravels consist of well-rounded pebbles and boulders. The latter were derived from the bedrock mass of the Sierras, and consist of granite, schist, granodiorite, and other rocks. In the early days the most productive part of the channel was in Little Valley, several miles southwest of Franktown. It is reported that placer gold

value of \$60,000 was taken from one pocket. Mining was hindered by the large amount of water and a number of faults, which displaced the gravels.

OLINGHOUSE DISTRICT

The Olinghouse or White Horse district is on the east slope of the Wilcox Mountains of the Virginia Range in southeast Washoe County, about nine miles west of the town of Wadsworth. The district was first prospected in 1860. Prior to 1900 the placer deposits in Olinghouse Canyon were of considerable local importance and the production of placer gold, although not definitely known, reached many thousands of dollars. It is known that the residents of Wadsworth worked the placers for a number of years with pans and rockers, and earned more than wages for their efforts. The gold is fairly coarse and the deposits shallow, and that the best parts of the placer ground were worked quite thoroughly in the early days. In 1932 there was some placer activity in the district, but the results of this work are not known.

PEAVINE DISTRICT

The placer deposit in the Peavine district is in Washoe County, six miles by road northwest of Reno on the northern slope of Peavine Mountain. The lode deposits in the district were discovered in 1863, and it is interesting to note that the first rail shipment over the Sierras consisted of ore from this district shipped to Sacramento in 1866.

The only record of placer mining in the district covers the years 1876 to 1881 and the early nineties. The placer area is located in a narrow ravine, and was 1,500 feet long and from 2 to 3 feet deep, judging by the old workings. Several springs in the vicinity furnished water for sluicing, and when this water supply failed, dry washing equipment was employed. It is said that a number of rich boulders of ore were found while placer mining.

There has been no placer mining in the district in recent years.

WHITE PINE COUNTY

BALD MOUNTAIN DISTRICT

The Bald Mountain or Joy district is in the northwestern part of White Pine County on the western slope of the Ruby Range, at an elevation of 7,400 feet above sea level. The district was discovered in 1869 and placer gold was mined in the early days, principally by Chinese. The production of placer gold was small. The placer gold is found in Water Canyon and tributary ravines.

The old workings in Water Canyon are outlined by pits and workings extending up the canyon for about a mile west of the abandoned camp of Joy. The richest part was near the lower end of Water Canyon where the channel is narrow and the gravel is 10 feet deep. At this point the pay streak on bedrock is 18 inches thick, overlain by 6 to 13 feet of overburden. The gravel contained a little gold irregularly distributed. The gold in the bedrock was fairly coarse, and nuggets ranging in value from \$2.50 to \$10 were found. Concentrate from the gravity separation of scheelite (calcium tungstate), a heavy white mineral, makes a separation of the gold more difficult.

The scarcity of water and the short mining season made placer mining difficult. Small scale methods were used by individual miners. In recent years numerous unsuccessful attempts have been made to work placer claims in the district.

OSCEOLA DISTRICT

The Osceola district is on the west flank of the Snake Range in southwestern White Pine County, 40 miles southeast of Ely.

The first placer discovery in the district was made by John Versan in 1877. The placers are distributed over a wide area which includes Dry Gulch and Grub Gulch in the immediate vicinity of the town of Osceola, Weaver Creek and the Dry and Summit placer diggings. Estimates of the total value of placer gold in the district range from \$2,000,000 to \$5,000,000.

The main placer workings are in Dry Gulch and Grub Gulch which are the principal drainage channels in the immediate vicinity of Osceola. The most productive placer areas in Nevada occur in these two gulches and their alluvial fans. The gulches are dry the greater part of the year and the only water available is from small springs nearby.

The placer deposits in Dry Gulch and Grub Gulch are 10 to 25 feet deep at the upper ends of the gulches and 25 to 50 feet at the lower parts. Usually the gold is more or less distributed through the gravels, but the principal pay streak is near the surface. The bedrock is shale, limestone and quartzite. The gravel contains but few large boulders. The gold is both fine and coarse. Several large nuggets were found in the early days, one of which was worth about \$5,000 and the others about \$2,500 each. The gold is about 850 fine.

For several years following their discovery, these placers were worked by ground sluicing, rockers, and sluice boxes where water was available. It is reported that about 350 placer miners

working in the two gulches from 1877 to 1880. In the early thirties the important placer locations in Dry Gulch were consolidated and the Osceola Placer Mining Company organized to work the deposits on a large scale by hydraulicking and sluicing. This company constructed, at a cost of \$200,000, ditches having a total length of approximately 34 miles. Water was brought in from several creeks heading around Wheeler Peak. The company continued work until 1900 when the gravels below the ditch lines were worked out. Since 1900 placer mining has been carried on intermittently in the two gulches with rockers and dry washers. In 1931 and 1932, from 20 to 40 men were placer mining in the gulches, but in general the results of their efforts were not encouraging, as nearly all the richest gravels were worked over in the early days.

The Weaver Creek placer diggings are east of the divide, about four miles distant and higher than the camp of Osceola. In the early days a considerable area at the upper end of the creek was worked by Chinese. In 1932 an attempt was being made to work the gravels adjacent to the creek by sluicing. The gravel was excavated and transported to the sluice by a small drag line derrick. The operations were hampered by large boulders and water on the bedrock. In addition the placer operators became involved with ranchers below the placer workings over water rights.

The Hogum placers are three miles southwest of Osceola, on an alluvial fan which spreads out from Mary Ann Canyon. Pay gravel was found here in 1879, and the deposits have been worked intermittently since that time.

The deposits occur usually in strata overlying cemented false bedrock. In places the pay streak is on bedrock. The pay gravel is worked by sinking shafts and drift mining. The material is hoisted by small power hoists, or by windlasses. In the spring of the year when water is available the gravel is sluiced. The gravel is finely divided.

In 1931 and 1932 from 15 to 20 lessees were working in the Hogum placer areas with varying success.

The Summit Diggings are near the crest of the divide several miles above Osceola. In 1932 considerable excitement was caused over the reported discovery of rich placer gravel in the area. A large number of claims were staked out by miners from the area, but after considerable prospecting many of the miners withdrew.

HOW BULLION IS PAID FOR AT THE UNITED STATES MINTS

Gold from the mines reaches the mint in the form of cakes and bars, nuggets, grains, and dust, nearly free of impurities. The larger producers usually reduce the gold to the form of cakes, which is the most desirable form. Native gold, though it has been melted, is generally the product of the placer mines. As a rule it contains impurities in the form of iron or particles of quartz, or minute pieces of iron or lead. These impurities cause a loss in weight when refining the gold. The loss varies from 2 to 6 per cent of the gross weight. Gold cakes are derived from either lode or placer gold. Sometimes mercury has been used and the amalgam retorted. The loss of gold gives the greatest loss in melting because the mercury usually has not been completely retorted. The shrinkage from incomplete retorting of the mercury may range from 1 to 2 per cent of the gross weight.

The regulations covering the receipt of gold bullion at the United States mints state that a deposit must ordinarily have a \$100 value before it can be received. However, as a concession to a small placer miner a temporary order, issued June 2, 1901, authorizes the mints to accept a deposit of \$40 or more in value.

Deposits of gold may be made at the mints in person, by mail or express, or the owner may employ a correspondent to deposit it for him. When forwarding crude gold to the mint it is necessary to prepay transportation charges, and also to send by separate mail a letter of instructions which contain the name of the depositor, the approximate weight and estimated value of the gold, what method of payment is desired; whether in bars or bullion, on the Treasurer of United States, or by cash for bars or bullion by express or registered mail. For the purpose of enabling the mint to compile correct statistics, depositors of crude gold from mines are required to state the name of the mine or mining district.

The methods and processes of assaying, refining, and determining the value, and payment of gold sent in by depositors are conducted in an ordinary business-like manner, and in such a way as to insure accuracy and promptness in making returns. Payments are made in from two to five days after they are received. The gold of gold is kept separate until after it is melted, assayed, and the exact value ascertained, based on the weight after melting.

In the process of assaying gold and silver bullion, the weight is fixed 1,000 units as a base for determining purity. Thus, if the gold is said to be 780 fine it contains 780 parts of pure gold of 1,000 in the troy ounce, and the value per ounce

multiplying the value per ounce 1,000 fine (\$20.6718) by 0.780. Thus, gold which is 780 fine is worth \$16.12 per troy ounce. Silver, free from gold, is not purchased by the mint unless needed for the manufacture of coin.

The government pays the depositor for all the gold and silver in a deposit, excepting a very slight deduction on the silver. It is impracticable to extract all the silver contained in gold in the process of refining and parting.

No allowance is made for platinum or other metals which may be present in the bullion. Deposits containing 800 thousandths or more of base metals will not be received at the United States mints.

The weight of the bullion is measured to $\frac{1}{100}$ part of an ounce. The fraction of the hundredth part of an ounce inures to the government. In establishing the fineness of the bullion in dealing with crude gold the fineness is determined to $\frac{1}{2}$ of one-thousandth; in fine gold the fineness is reported to $\frac{1}{4}$ of one-thousandth.

On each deposit of crude gold sent to the mint for disposition, the government deducts a melting charge which amounts to \$1 for the first 1,000 ounces, computed on the after-melting weight. The charge for making fine-gold bars is 6 to 9 cents per \$100, according to the size of the bars.

The charges for separating and refining bullion containing both gold and silver are based on actual cost, varying from $\frac{1}{2}$ to $8\frac{1}{2}$ cents per gross ounce, or a fraction thereof. In addition, the depositor must pay for the amount of copper required to alloy gold for coinage purposes. The copper required is $\frac{1}{10}$ of the fine weight of the gold. The copper is charged for at the rate $1\frac{1}{2}$ cents per ounce.

Ordinarily there are no deductions of the weight of the gold received at the mint. Sometimes, however, a deposit of crude gold is received which fails to give concordant assays owing to the presence of a large percentage of base metals. At the discretion of the melter and refiner, with the approval of the mint superintendent, deductions are made for a toughening charge in order to protect the government against any loss which would be sustained if the deposit were accepted at its full weight. Such deductions are made only in extreme cases.

PLACER MINING LAWS

The present United States Mining Law was passed May 10, 1872, and with some additions and amendments is the law which governs present mining.

The mining laws of the United States and the State establish the manner in which lode and placer claims are located and patented. There is a definite course to follow in order to obtain and hold possession of a mining claim on government land. Unless these legal rules are strictly followed, the locator of a claim may lose it, even after having done sufficient work to prove its value.

The following excerpts from the United States and Nevada mining laws supply information most important to the locator. Copies of the complete Nevada State and Federal Mining Laws may be obtained from the Secretary of State, Carson, Nevada.

UNITED STATES MINING LAW

Citizenship

Citizens of the United States, and those who have declared their intention to become such, may locate or purchase mining claims on both surveyed and unsurveyed government lands.

Proof of citizenship may be made by an individual affidavit. In an association of persons, the affidavit of a duly authorized person is required. For a corporation, the copy of their charter or certificate of incorporation is required. (Secs. 2319-2312.)

Lands Open for Placer Location

Claims called "placer," and subject to location as shown on all types of mineral deposits excepting quartz veins, may be located in place. They are subject to entry and patent under the same rules as similar to vein and lode claims, but where the lands are surveyed by the United States, the limits of claims must conform to legal public land subdivisions. An actual discovery of valuable mineral on the ground is necessary in order to locate the location of a placer mining claim.

Subdivision of Claims

Legal subdivisions of 40 acres may be subdivided into smaller tracts, and two or more persons, or associations of persons, may locate contiguous claims of any size, although such claims are less than 10 acres each, may make joint entry thereon. The location of a placer claim shall exceed 160 acres for a single person or association of persons, which location shall conform to the United States surveys; and nothing contained in this section shall be construed to authorize a bona fide preemption or homestead claim upon agricultural lands, or authorize the sale of the improvements of any bona fide settler to any purchaser. (Sec. 2330.)

Placer Locations Must Conform to Public Surveys

Where placer claims are upon surveyed lands, and conform to legal subdivisions, no further survey or plat shall be required. All placer claims shall conform as nearly as practicable with the United States system of public land surveys. No location shall include more than 20 acres for each individual claimant. Where placer claims cannot be conformed to legal subdivisions a survey and plat shall be made as on unsurveyed lands.

The Government requires that all claims be in compact form, and the Department of the Interior will not approve "shoestring" claims, that is, long and narrow or crooked claims as a rule. When located on unsurveyed land, claims must be rectangular and laid out east and west, and north and south. If the boundaries of other claims interfere, the locator may conform his boundaries to those of the interfering claims. (Sec. 2331.)

Gulch Placers Are Exception

Where the mineral placer ground is confined within a narrow canyon, the location need not conform to the legal land subdivisions. The Department of the Interior has made a special ruling involving narrow canyon placer claims, and also narrow gulch claims.

Secretary Teller held that the placer law of 1870, which expressly required placer locations to conform to the lines of the public surveys, was unreasonable, a hardship, and in contravention of the established custom of the mining regions; therefore it was modified by the Act of May 10, 1872, so as to provide for exceptional cases where reason and common sense required a different regulation.

The Supreme Court of California in a comparatively recent period has recognized the right of a placer locator on surveyed lands to make a location in an irregular form and not conforming to the public surveys. (Lindley on Mines, vol. 2, pp. 1046-1047.)

NEVADA PLACER LAWS

The Compiled Laws of Nevada, 1929, contain the following sections:

Location of Placer Claim

4132. The location of a placer claim shall be made in the following manner: By posting thereon, upon a tree, rock in place, stone, post, or monument, a notice of location, containing the name of the claim, name of locator or locators, date of location, and number of feet or acres claimed, and by marking the boundaries and the location point in the same manner and by the

same means as required by the laws of this State the boundaries of lode claim locations; *provided*, that the United States survey has been extended over the land in the location, the claim may be taken by legal means, and, except the marking of the location point as prescribed, no other markings than those of said survey are required.

Relating to Location

4133. Within ninety days after the posting of the location of a placer claim, the locator shall perform not less than twenty dollars worth of labor upon the claim for the purpose thereof, and shall have recorded by the mining district and the county recorder of the district and county in which the claim is situated a certificate which shall state the name of the claim, designating it as a placer claim, name of the locator, date of location, number of feet or acres located, and a description of the claim with regard to some natural or permanent monument, so as to identify the claim, and the amount of work done by him as herein required, and the place on the claim where said work was done. This certificate, or the record thereof, or a duly certified copy of the same, shall be prima-facie evidence of the recitals therein. If the certificate do not state all the facts herein required, it shall be void.

The recorder shall receive a fee of one dollar for recording the same, and the person recording the claim shall be furnished with a receipt containing the name of the claim, date of location, and date of recording.¹⁶

Annual Labor on Mining Claims

1428. The amount of work done or improvements made each year to hold possession of a mining claim shall be as prescribed by the laws of the United States, to wit: One dollar annually. In estimating the worth of labor actually performed upon any mining claim, to hold the same, the laws of the United States, the value of a day's labor shall be fixed as the prevailing wages of the district in which the claim is situated; *provided, however*, that in the sense of the laws, eight hours of labor actually performed upon the claim shall constitute a day's labor. *As amended, Stats. 1891, c. 10, § 1428.*

Affidavit of Work Performed

4129. Within sixty days after the performance of the making of improvements, required by law to be performed or made upon any mining claim, the person

¹⁶State of Nevada, State and Federal Mining Laws pamphlet, 1891, p. 10.

behalf such labor was performed or improvements made, or some one in his behalf, shall make and have recorded by the mining district recorder or the county recorder, in books kept for that purpose, in the mining district or county in which such mining claim is situated, an affidavit setting forth the amount of money expended, or value of labor or improvements made, or both, the character of expenditures or labor or improvements, a description of the claim or part of the claim affected by such expenditures, or labor or improvements, for what year, and the name of the owner or claimant of said claim at whose expense the same was made or performed. Such affidavit, or a copy thereof, duly certified by the county recorder, shall be prima-facie evidence of the performance of such labor or the making of such improvements, or both.

Assessment Work Relief Bill

In 1932 the United States Congress passed a relief bill waiving assessment work on mining claims for the assessment year of 1931-1932. The provisions of this emergency Act expired on July 1, 1932. Therefore, assessment work for 1932-1933 must be performed prior to July 1, 1933.

Unpatented Mining Claims Not Taxed

Prior to obtaining patent from the United States, mining claims are exempt from taxation, except as to improvements, buildings and machinery thereon. The mineral production of such claims, however, must be reported annually, and is taxed.¹⁷

Patented mining claims are assessed not less than \$500 per claim, excepting where \$100 in labor has been done on the claim during the calendar year.¹⁸

Grubstake Contracts Must Be Recorded

4173. All grubstake contracts and prospecting agreements hereafter entered into, and which may in any way affect the title of mining locations or other locations under the mining laws of this State, shall be void and of no effect, except between the parties to said contract or agreement, unless the instrument shall first have been recorded in the office of the county recorder of the county in which said instrument is made. The instrument or instruments shall be duly acknowledged before a notary public or other person competent to take acknowledgments. Grubstake contracts and prospecting agreements, duly acknowledged and recorded as provided for in this act, shall be prima-facie evidence in all courts of justice in this State in all cases

¹⁷State of Nevada, State and Federal Mining Laws pamphlet, pp. 35-38, 1931 edition.

¹⁸Op. cit., p. 39.

wherein the title to mining locations and other located under the mining laws of this State are in dispute.

Many mines have been discovered by prospectors who "grubstaked," that is, supplied with food and equipment, who, in return, are to share in discoveries, usually upon a percentage basis. In order to have proper legal standing such contracts should be recorded.

MINING ON RAILROAD GRANT LANDS

The Southern Pacific Railroad Company owns or controls rights in many thousands of acres of desert land in Nevada. A question is often asked: "What right have I to a mining discovery I have made upon railroad grant land?"

When railroad grant lands have been patented by the railroad company no one may obtain title to any mineral thereon the same, without first purchasing or leasing the land from the Southern Pacific Company, Land Department, San Francisco, California.

Therefore, the discoverer should first write to the Receiver, United States Land Office, Carson City, Nevada, to determine if the land has, or has not, been patented. If the railroad grant land has not been patented, a discovery of valuable minerals thereon should be located and recorded in the usual manner. The fact should be reported by letter to the Chief of the Mining Division, United States General Land Office, Custom House, San Francisco, California. The General Land Office then notifies the attention of Southern Pacific Company to the mineral character of the land, for lands of known mineral character were excluded from the railroad grant and may not be patented. If there is a controversy is then re-examined by mining geologists employed by the railroad company and also by mineral inspectors of the General Land Office. If the railroad company concedes the mineral character of the land, it is at once excluded from the railroad grant selection list. In case of disagreement between the railroad company and the General Land Office, a hearing is held before the Receiver of the United States Land Office at Carson City, Nevada. After the Receiver has heard the sworn testimony of all witnesses either side cares to present, he will render a decision as to the mineral or nonmineral character of the land in controversy, and eliminate from the railroad company's selection list all of the mineral land by legal selection, after which the mining locations thereon may be patented.

Such a determination of the mineral or nonmineral character of railroad grant lands selected for patent is entirely without regard to the locator of the mining claim thereon.

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The symbols following each reference have the following meanings:

*Available for consultation at large libraries.

†Obtainable from Superintendent of Documents, Washington, D. C.

‡Obtainable from Publications Section, U. S. Bureau of Mines, Washington, D. C.

§Obtainable from publisher.

M. & S. P.—Mining and Scientific Press.

E. & M. J.—Engineering and Mining Journal.

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BLANCE, NEVADA

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BRUCITE DEPOSIT, PARADISE
RANGE, NEVADA

A Preliminary Report

By
EUGENE CALLAGHAN

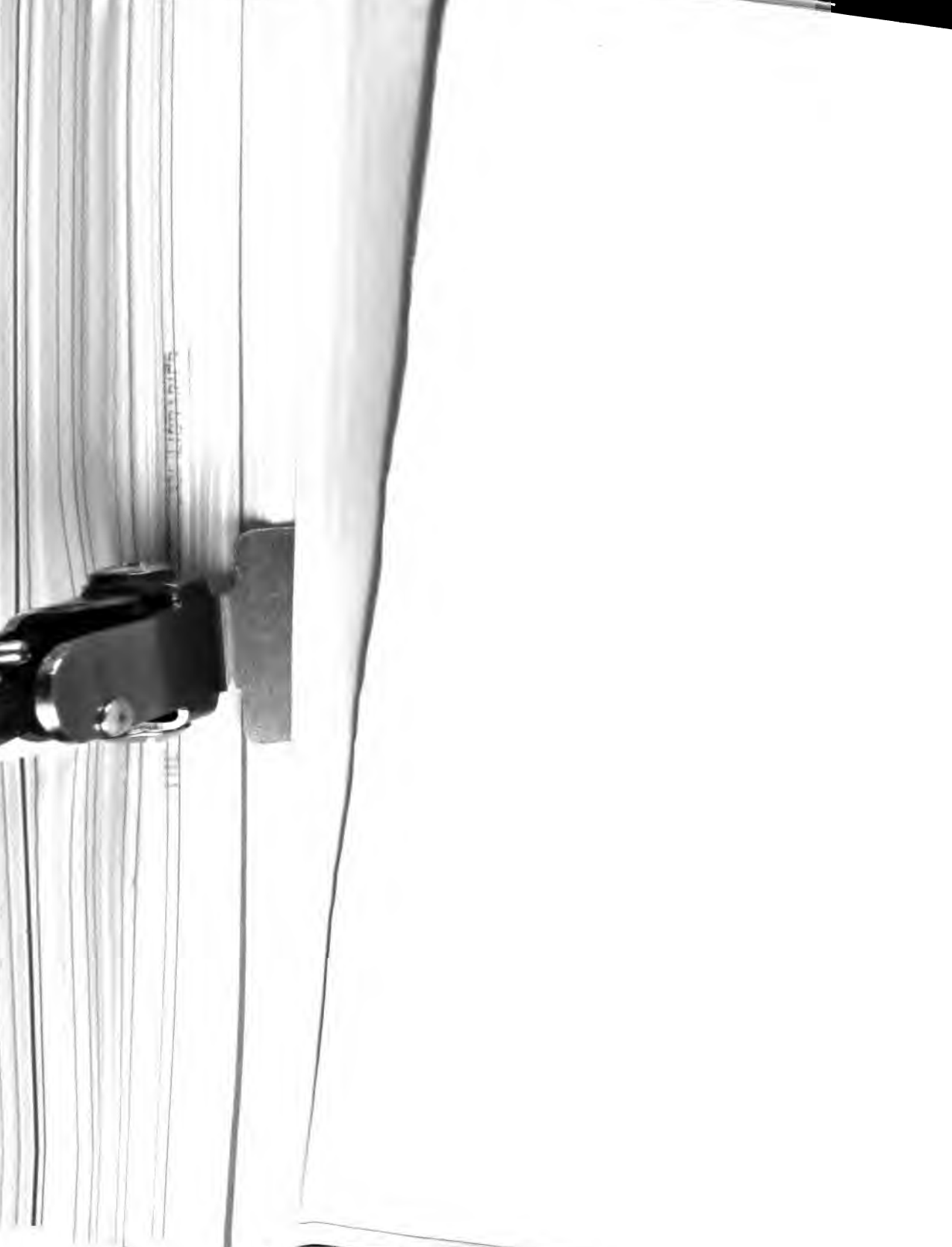
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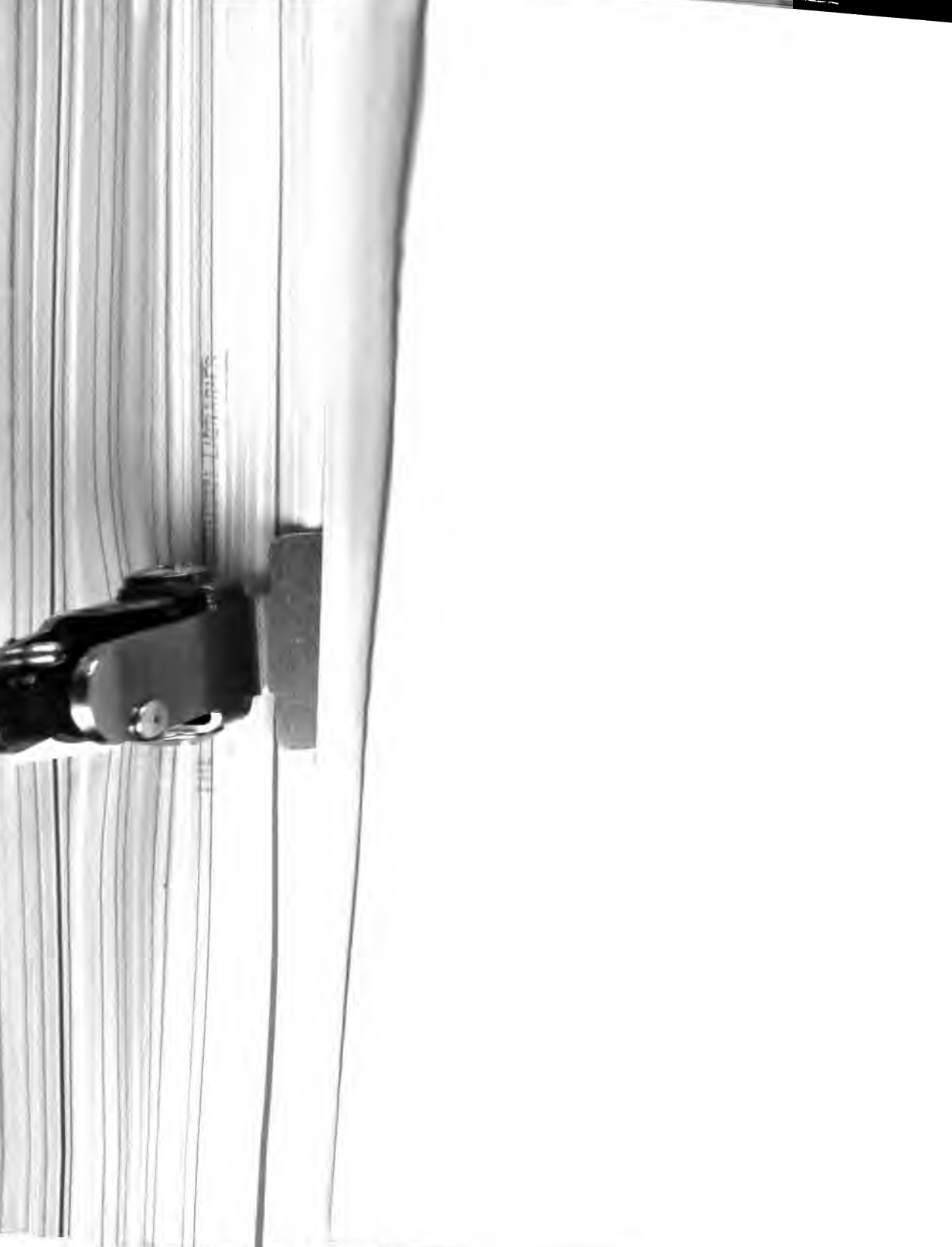
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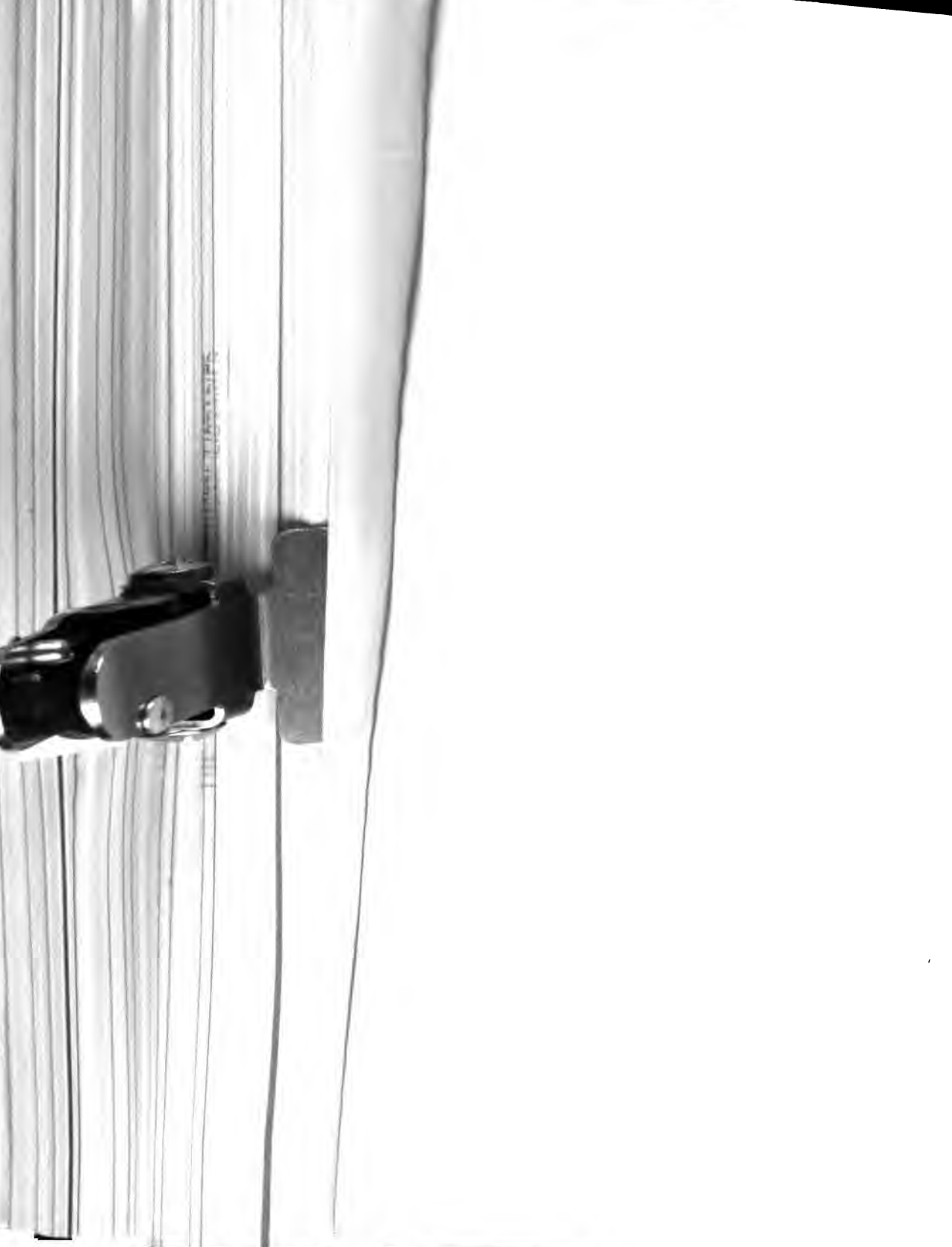
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BRUCITE DEPOSIT, PARADISE RANGE, NEVADA

A PRELIMINARY REPORT

INTRODUCTION

Brucite, the hydroxide of magnesium, is a comparatively common mineral which has been frequently noted as associated with serpentine but also occurs associated with a deposit of crystalline nesite in Washington. No occurrence of a deposit of sufficient size to be mined or quarried for brucite alone except the one here described has come to the writer's attention. Brucite contains a far higher theoretical percentage of magnesium oxide (60) or metallic magnesium (41.6) than any other naturally occurring magnesium compound except the rare mineral, periclase. In comparison, the chief sources of magnesium compounds, nesite, magnesium chloride, and dolomite contain 28.8, 25.5, and 12.6 per cent of metallic magnesium, respectively. No uses for brucite in its natural form have yet been developed, but on the basis of chemical proportions it has distinct advantages over nesite and magnesium chloride. Large masses of crystalline nesite are associated with the deposit, greatly increasing its commercial value.

The deposit of brucite on the west slope of the Paradise Range in northwestern Nye County is a new development. It was discovered late in 1927 and located on August 4, 1928, by H. E. Enger, who excavated a number of trenches and two shafts, the deepest 50 feet deep. The property was optioned to H. A. Severhaus and sold to the Standard Slag Company in June, 1930.

The United States Brucite Corporation, the present operating company, was organized in October, 1930. The Standard Slag Company began prospecting the property by means of the diamond drill in July, 1930, and completed its program July 31, 1931. Production has been limited to one carload shipped to Los Angeles in 1930 and small lots shipped to testing laboratories. Brief descriptions of the deposits have appeared in the chapters on Magnesium and its Compounds in "Mineral Resources of the United States" for the years 1927-1930, inclusive, issued by the United States Bureau of Mines.

The investigation upon which the present report is based occupies the greater part of the months of September and October, 1931, as part of the cooperative program between the U. S. Geological Survey and the State of Nevada. During the entire period the

author had the able assistance of Thomas P. T. a topographic map of the southeastern part of will appear in the final report, and plotted most the eastern part. On October 6, the party was E. Thomas, who rendered valuable aid and w for both the topography and geology of the w the area.

Throughout the investigation and subsequent had the whole-hearted cooperation of the owner Mr. Richard L. Smith, resident engineer, who ties of an excellent camp, maps, numerous cl reports, diamond drill cores and core records, an tion at the disposal of the party. The writer h of a day of consultation in the field with John A of the Mackay School of Mines and the State Professor Vincent P. Gianella, and the late Pr Jones, both of the Mackay School of Mines. Carpenter, of the same institution, very kind writer to examine an early report he had made Mr. H. G. Ferguson contributed the informati geology of the Paradise Range. Professor I Columbia University, obtained X-ray diffracti number of minerals, and W. T. Schaller, Ch Jewell Glass determined or aided in the determ ber of minerals. Mr. F. M. Spencer, U. S. M kindly permitted the use of a patent survey map shortly before the writer's arrival. This map for the topographic and geologic map.

GEOGRAPHY

LOCATION

The deposits of brucite and magnesite descri are located on the rugged western slope of the I northwestern Nye County, Nevada. They lie moth mining district, and the area embraced in claims of the United States Brucite Corporation Sec. 26, most of the north part of Sec. 35, part $\frac{1}{4}$ of Sec. 36, and a small fraction of the southw all in T. 12 N., R. 36 E. (M. D. B. & M.). The by the map submitted with this report inclu ground partly or wholly covered by unpatente patented claims on a tungsten property and a n to the Nevada-Massachusetts Company, Inc.

Prospect site
 Tunnel
 Shaft
 Second drill hole
 Quarry
 Building
 Road
 Scale
 0 50 100 200 400 800 1600 ft





FLORANCE

GLORIA EXTENSION

TOPOGRAPHY

The area represented by the map includes a part of the deeply dissected western slope of the Paradise Range, as shown in Figure 4, which is contrasted with the more mature rolling upland that makes up the broad top of the mountains. It also includes the subdued topography at the base of the range and the dissected alluvial fans and pediments that slope into the broad basin of Gabbs Valley. Slopes including and east of the brucite deposits are steep and broken by small cliffs. They average between 20° and 55° over more than half of the area. The total relief within the mapped area is 1,300 feet. The assumed altitude at the camp is 5,130 feet, at the lower deposit of brucite, 5,320 feet, and at the center and south end of the upper deposit of brucite, 5,595 feet and 5,860 feet, respectively.

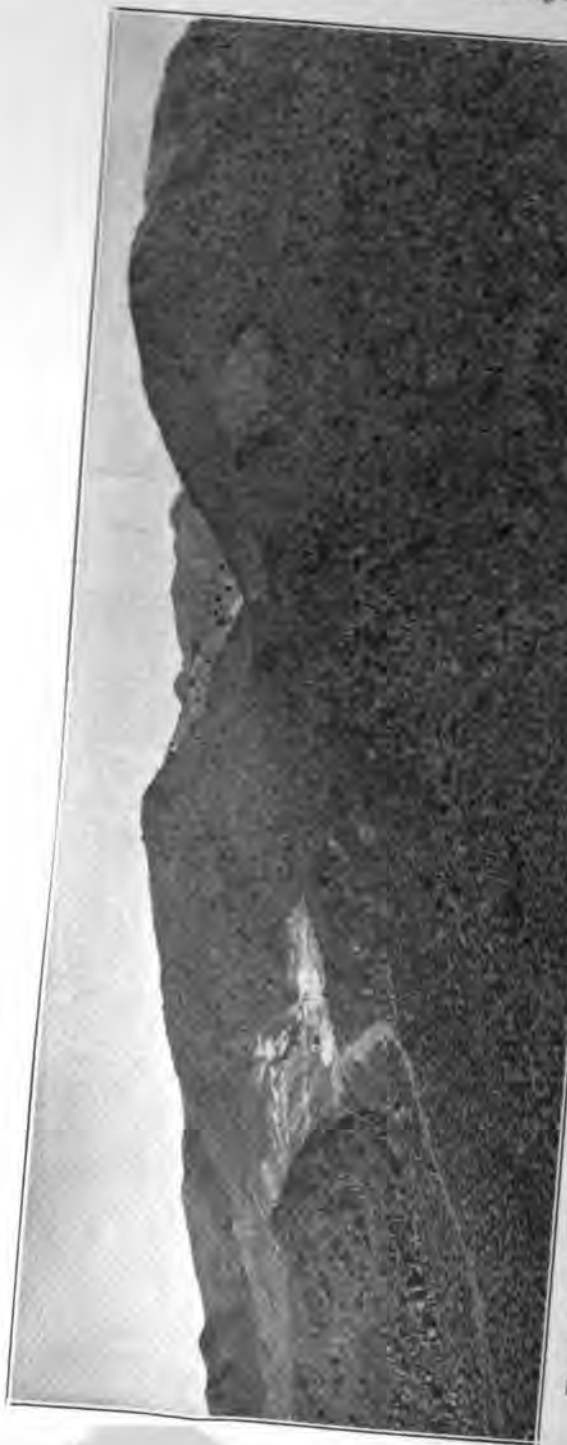
Two washes, the northern one known as Tungsten Gulch and the southern known as Granite Gulch, drain the area. They contain water only during periods of exceptional rain or melting snow. These washes maintain tortuous courses within the steeply dipping beds of dolomite in their upper courses, but assume more gently curved courses in the granodiorite and in the area of alluvial fans and pediments to the west.

TRANSPORTATION

The brucite area is reached by desert roads which follow washes for part of the distance. One road, 33 miles in length, approaches the deposit from Luning on the Mina branch of the Southern Pacific Railroad. It crosses the Gabbs Valley Range, involving an ascent of 2,000 feet. Another, nearly 40 miles long, allows access to the deposit from the Lincoln Highway near Westgate by way of Broken Hills. The distance by road to Reno is 158 miles. Plans for development of the deposit call for a railroad 55 miles long joining the Southern Pacific at Schurz, north of Walker Lake. With some improvements and changes in route the roads could be used by trucks at all times except periods of rain or melting snow, which in this arid climate are ordinarily widely separated.

CLIMATE

The brucite deposit lies within the arid region of westcentral Nevada. The rainfall is generally less than 10 inches and the amount falling as snow is slight. It is a region of barren mountain ranges, separated by broad valleys, bordered by alluvial fans, and containing light-colored or white playas. Vegetation is largely limited to sagebrush, which is here anything but luxuriant. The brucite deposit lies within the Toiyabe National Forest, but



There are only a few trees, pinon and juniper, on the property. These trees, however, are sufficiently numerous to darken the bland part of the range, especially to the south.

As there are no permanent streams or springs, water must be obtained from wells. Shallow wells and cisterns in granodiorite and Granite Gulch, a short distance above the camp, were found to furnish sufficient water for domestic purposes, but not enough for drilling and other commercial uses. The situation was aggravated by several abnormally dry seasons, but the water supply is best would be insufficient for large-scale operations. Water from wells in the floor of Gabbs Valley, where the water table is 10 or 50 feet below the surface, is reported to be unfit for normal uses. However, there are reported to be more springs in the Paradise Range than are commonly found in similar areas.

GENERAL GEOLOGY

INTRODUCTION

That part of the Paradise Range within a radius of six miles of the brucite deposit is composed mainly of limestone and dolomites of Upper Triassic age which have been intruded by several rocks of granodiorite and granite and numerous dikes and sills, according to information supplied by H. G. Ferguson.¹ Lower Triassic rocks occur at Paradise Peak. Tertiary formations overlie parts of the range to the south and east. The dip of the sedimentary formations along the western part of the range is to the west, though complicated by minor flexures and interrupted by intrusive bodies.

The deposits of brucite and magnesite lie on either side of a tongue of granodiorite projecting to the northwest beyond the main mass, which is approximately 6,500 feet wide at the south side of the mapped area. They are associated with dolomite which has been recrystallized or marmorized under the influence of solutions rather than under stresses. Little semblance of original structures remain. This material either grades into or is in sharp contact with very fine-grained, finely laminated, nearly black dolomite, which elsewhere grades into fossiliferous Upper Triassic limestone, according to H. G. Ferguson.² The deposits of brucite and magnesite as well as the recrystallized dolomite are believed to be the products of the action of hypogene magnesian solutions upon preexisting dolomites, probably as a consequence of the granodioritic intrusion but not necessarily related closely to its present form.

¹Personal communication.

²Personal communication.

SEDIMENTARY ROCKS

The primary sedimentary rock of the mapped area is a gray dolomite which is very fine grained (0.07 mm) and is so laminated that it splits readily along bedding planes. It is so minutely jointed that over much of the area it breaks into small rhombic fragments, and on the weathered surface is characterized by solution trenches along fractures. Chert nodules diverge only a few tenths of a per cent from the composition of the mineral dolomite, but locally it contains iron oxide and talc. Recrystallized chert nodules were found in the west part of Tungsten Gulch. Stain of iron oxide is present in some of the material and probably represents former chert. It contains 0.01 per cent of sulphur. The dark appearance is due to finely divided carbonaceous matter, as bituminous shale is noted in this formation elsewhere in the range. This rock is not as it was originally deposited, but has the structure as though recrystallized under regional metamorphism and its impurities have crystallized locally as trace minerals.

The recrystallized dolomite differs but a few per cent in chemical composition from the original dolomite, but greatly in appearance. Some of it retains a part of the original rock, but is white. Other parts are gray. The weathered surface and light to dark gray on fresh surfaces. Crystals are equant and interlocking and generally 0.2 and 1.0 mm. in diameter. Original structure is wholly obliterated. Areas that have been changed to magnesite resemble the recrystallized dolomite so closely that in some places it is impossible to distinguish them in the field. The magnesite is more sugary in the outcrop than the dolomite. The minor chemical constituents of magnesite differ from those in dolomite.

INTRUSIVE ROCKS

A stock of granodiorite characterized by biotite and hornblende is the principal igneous rock and underlies about one third of the area. Only a part of the stock is exposed in the area, however. The color is light gray to pinkish. It contains biotite and less conspicuous hornblende. The grain size is variable, but averages between 1 and 2 mm. The texture is uniform almost throughout. In only two or three places anything resembling flow-structure or linear patterns are observed. Jointing is very irregular. Aplite is common, but pegmatites are lacking except at the contact. In places the granodiorite weathers more readily than the dolomite, producing an arkosic soil. A slight difference in the

minerals, particularly quartz, may in part be responsible for this condition.

Under the microscope the granodiorite is found to consist of an interlocking aggregate of plagioclase, both andesine and sodic feldspar, a little orthoclase, quartz, biotite, hornblende, magnetite, apatite, and titanite. Andesine crystals are large and nearly equiaxed, whereas oligoclase, which has a dusty appearance, is interstitial among them. Hornblende and apatite have corroded borders. Orthoclase occurs in irregular areas between the other minerals. The amount of secondary minerals is very slight. Only a little sericite and a slight green coloration in the biotite was observed.

Chemically the granodiorite is very similar to other granodiorites and very closely parallels granodiorite from Nevada City, Calif.³ Though the granodiorite has invaded and apparently assimilated dolomite, the proportions of lime and magnesia do not exceed those in granodiorites that invade other rocks.

Though the general form of the stock is broad and blunt across the northern end, there are numerous projections. The largest is at the contact between the two deposits of brucite. Projecting out beyond the altered dolomite and magnesite are numerous apophyses in the form of dikes, sills, and irregular masses, many of which do not connect at the surface with the main mass. Some of these smaller masses occupy spaces in the sedimentary rocks or their weathering products, but others have followed earlier fine-grained veins, brecciating them and thus forming a peculiar form of composite dike. Commonly an aggregate of fragments of earlier igneous rocks or earlier consolidations of the granodiorite is found clustered near the contact. No inclusions of the carbonate rocks more than 10 feet in length were found in granodiorite.

Many granitoid dikes and lenses ranging from a fraction of an inch to 10 or 15 feet in width occur near the granodiorite contact, but are far more numerous in brucite than in either dolomite or magnesite. Most of the lenses within the brucite are thoroughly shattered and surrounded by a zone of contact minerals, a fraction of an inch to several inches in width. The host rock has a soapy, greenish gray appearance. The size of the lenses averages nearly 1.0 mm. Under the microscope these rocks are found to consist chiefly of perthitic plagioclase, quartz, and hornblende, though very slightly pleochroic augite with apatite and magnetite. Rarely these dikes are pegmatitic and consist chiefly

³Washington, H. S., Chemical analyses of igneous rocks: U. S. Geol. Survey Prof. Paper 99, pp. 258-259, 1917, from Lindgren, Waldemar, The gold veins of Nevada City and Grass Valley districts, Calif.; U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 38, 1896.

of oligoclase and andesine, quartz, and large euhedral crystals. The evidence of activity of solutions late in the history of the rock, effecting the primary consolidation of the rock, is shown by the fact that Plagioclase has been veined by more alkalic feldspar and that the magnesian minerals on the other hand show no evidence of replacement. There are also numerous veinlets and irregular aggregates of chlorite and micaceous radiating aggregates of chlorite mineral. There are also veinlets of carbonate. This mineralogic change has been accompanied by a distinct change in chemical composition as compared with normal granodiorite, causing an increase of over 10 per cent in MgO , of over 3 per cent in K_2O , and of nearly 10 per cent in chemically combined water, chiefly at the expense of the oxides of iron. As these are not normal igneous rocks, they cannot be classified on a strictly magmatic basis. Because of the low silica (58.52 per cent), the presence of more than hornblende or biotite and the nearly equal amounts of plagioclase and plagioclase in the norm, they may be classified as monzonite.

In addition to the granodiorite and the monzonite, there are numerous dikes and some sills of various compositions and of different ages, some of which traverse both the granodiorite and carbonate rocks. Most of these have been mapped and are shown in Figure 1 because of their slight thickness and complexity. Many of the dikes are earlier than the granodiorite and an equal or greater number are later. Those dikes which cut the granodiorite include a very fine-grained black andesite, a fine-grained, gray biotite andesite, and a frequently found contained within the granodiorite. The fine-grained aplitic granodiorite consisting largely of quartz and quartz, generally with phenocrysts of biotite and quartz. The dikes are chiefly medium and very fine-grained and porphyritic lamprophyres which are abundant in the area and extend uninterruptedly into the carbonate rocks. There are at least two relative ages of lamprophyric dikes. The older dikes in the area consist of light or medium gray andesite and traverse all other dikes, and furnish excellent examples of flow and striations, indicating a high degree of viscosity and movement. The fact that it had sufficient viscosity to carry along pieces of other rocks is indicated by the presence of granodiorite in the dike 1,200 feet north of the main crop of granodiorite. This fact strongly suggests that the granodiorite stock extends further north at depth.

The age of the granodiorite, like that of similar intrusives in western Nevada and in the Sierra Nevada, is believed to be Upper Jurassic or Lower Cretaceous. It is later than the Lower Jurassic and clearly antedates the Tertiary, which is the next system represented. The intrusive rocks older than the granodiorite probably belong to the same general magmatic and orogenic period, and the intrusion of the lamprophyres undoubtedly followed the complete consolidation of the granodiorite closely. The rhyolite dikes may be of distinctly later, possibly Tertiary, age.

REGIONAL METAMORPHISM

The fine-grained dolomite has undergone physical changes and probably also chemical changes since its deposition. No evidence is furnished by the area under consideration on the problem of gradation from limestone to dolomite. The dolomite has been recrystallized with an elongation of the crystals parallel to the bedding and its original bedding structures are thereby accentuated rather than obscured. Talc and tremolite have been developed in the less pure layers. Pyrite crystals or limonite pseudomorphs after pyrite is almost universally present in very small amounts. Former chert nodules have been changed to a granular aggregate of quartz. This metamorphism is probably in part a result of pressures that accompanied folding and in part a result of igneous intrusion.

CONTACT METAMORPHISM

In Granite Gulch east of camp the finely laminated dark dolomite comes in direct contact with the granodiorite with only a zone of whitened dolomite six inches to one foot in width intervening. At this point the lamination of the dolomite is bent down sharply into the granodiorite. At other points, where the intrusive rock is in contact with altered dolomite or magnesite, these rocks may contain contact minerals, particularly a light green serpentine of the bowenite group. This material is most abundant near the contacts, but may occur in veinlets and irregular masses in both brucite and carbonate rocks. Its structure and relations indicate that it is of hydrothermal origin. Contact silicates other than those belonging to the chlorite group are not as abundant as might be expected. There is a large area of contact rock containing garnets and tremolite north and northwest of the camp. Isolated occurrences include a small mass containing large poikilitic garnets in contact with a granodiorite dike near the center of the west sideline of Gloria Extension No. 3

claim, and a mass of garnet and minerals of the chlorite on the northwest side of the included mass of dolomite and magnesite southeast of the lower deposit of brucite. Some of the dolomite and magnesite contains chondrodite, garnet (garnet) and apatite. Generally there is a selvage of dolomite and contact minerals, such as serpentine, between brucite and diorite. A hard brown rock containing dolomite and magnesite, generally weathering to a porous mass occurs at a number of places, particularly at the top of the mountain near the surface of the upper deposit of brucite.

A feature of the contacts between granodiorite and dolomite or magnesite and between brucite and dolomite or magnesite is the development of compact or "bone" magnesite. This bone magnesite is white, hard, and porcelainous, and generally occurs in a cluster of nodules. One of these aggregates of "bone" magnesite occurs at the contact of brucite and crystalline magnesite in the lower deposit of brucite, and another occurs on the west side line of Gloria Extension No. 3 claim. This bone magnesite is commonly associated with the hard brown contact zone previously mentioned. Beyond the south end of the upper deposit of brucite some of the masses of "bone" magnesite are up to 10 feet in their maximum dimension. Bone magnesite occurs in veinlets and concretionary masses in granular magnesite.

The contact of granodiorite or quartz diorite and dolomite is generally marked by a contact zone from one to two inches in width, consisting chiefly of chondrodite, bone magnesite, apatite, garnet, muscovite, serpentine, and carbonate.

None of the fine-grained dikes of any kind have shown any noticeable contact metamorphism of the carbonate rocks.

HYDROTHERMAL METAMORPHISM OF DOLOMITE

The finely laminated dolomite has been changed in much of the area to a generally more coarsely crystalline material of dolomite and magnesite. The greater part of this altered material lies east and northeast of the large mass of granodiorite. Its western part, which is not clearly marked by a narrow strip west of the granodiorite and continues in an easterly direction past the northwest corner of Busta Extension and beyond the limits of the area. Its eastern boundary is at the granodiorite contact in the northwestern part of No. 4 claim, and extends easterly nearly to the north side of Gloria No. 5, and thence northerly following an irregular line with embayments and islands through the tungsten

passing Tungsten Gulch, and continuing beyond the boundaries of the mapped area. Material in this area is characterized by brown, white, or yellow colors on the weathered surfaces and complete or nearly complete obliteration of original structures.

The contact between the original dolomite and this altered mass east of the granodiorite is very irregular, with numerous bayments and islands, particularly of brown recrystallized material, in the dark finely laminated material. Some residual masses of unaltered dark dolomite remain in the recrystallized material. It might be expected that the alteration would follow the bedding, but such is found to be true in only a few very limited areas. The general dip of the contact is approximately vertical. The penetration of the dark dolomite by the recrystallized dolomite and magnesite takes several different forms: in places there are numerous veinlets of coarse-grained dolomite, which may or may not contain magnesite, penetrating the dark material; in other places large crystals of dolomite and magnesite have grown in the dark dolomite; in still other places magnesite with some dolomite has formed along a system of cross fractures and has replaced part of the dark dolomite, leaving closely spaced cores of the dark material and forming a replacement breccia. The structure of this replacement breccia shows most conclusively that magnesitization and recrystallization were accomplished by percolating solutions and not as a result of direct contact metamorphism by granodiorite or by any special application of heat and pressure.

Another effect of this alteration is the apparent expansion of the rock on recrystallization. This was observed particularly well at the north end of the Buster No. 1 claim. Laminae of the dark dolomite were found to be curved around concretion-like bays and masses of the recrystallized material. Some of the laminae pass into the mass and are distorted and largely obliterated, indicating that replacement as well as expansion took place.

At other points along the contact evidence of expansion was largely lacking because laminae could not be traced from the altered material into the recrystallized dolomite or magnesite. At a number of points there appears to be a marked change in structure in passing from one type of rock to the other. Where the structure can be made out in the recrystallized material the dip is found to be less steep than that in the original laminated dolomite nearby.

The reason for the generally lenticular form of the magnesite masses within the recrystallized material is not clear. It may be suggested, however, that the masses of magnesite in the dark

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dolomite represent the extreme activity of the solution after using up their magnesium in the replacement, capable only of recrystallizing the remaining dolomite without any further chemical change.

The formation of brucite is believed to be a different phase of this activity. The evidence will be treated more fully later.

STRUCTURE

In general the structure of the mapped area is a simple one, dipping toward the west. The average strike of the bedding is approximately north, and the dip is from 20° to 40° ; however, there are so many twists and turns and local variations in the bedding with reversals of dip that averages have little value.

As there are no horizon markers in the dolomite area, no definite evidence of faulting antedating the brucite or the intrusive rocks could be obtained. The ridge north of the fork of Tungsten Gulch outside the area appears from the topography to have a number of breaks, but their existence was not proved. No faults were found offsetting either the numerous sills or the granodiorite. The apparent offsets in the bedding are due to an original step-like arrangement, one part of the area dipping out and another beginning a little to one side. A thin layer of consolidated alluvium occurs in Tungsten Gulch at the northwest corner of the area, but has no expression on the present surface. There are many slickensided surfaces in the dolomite, but they are believed to be of local origin.

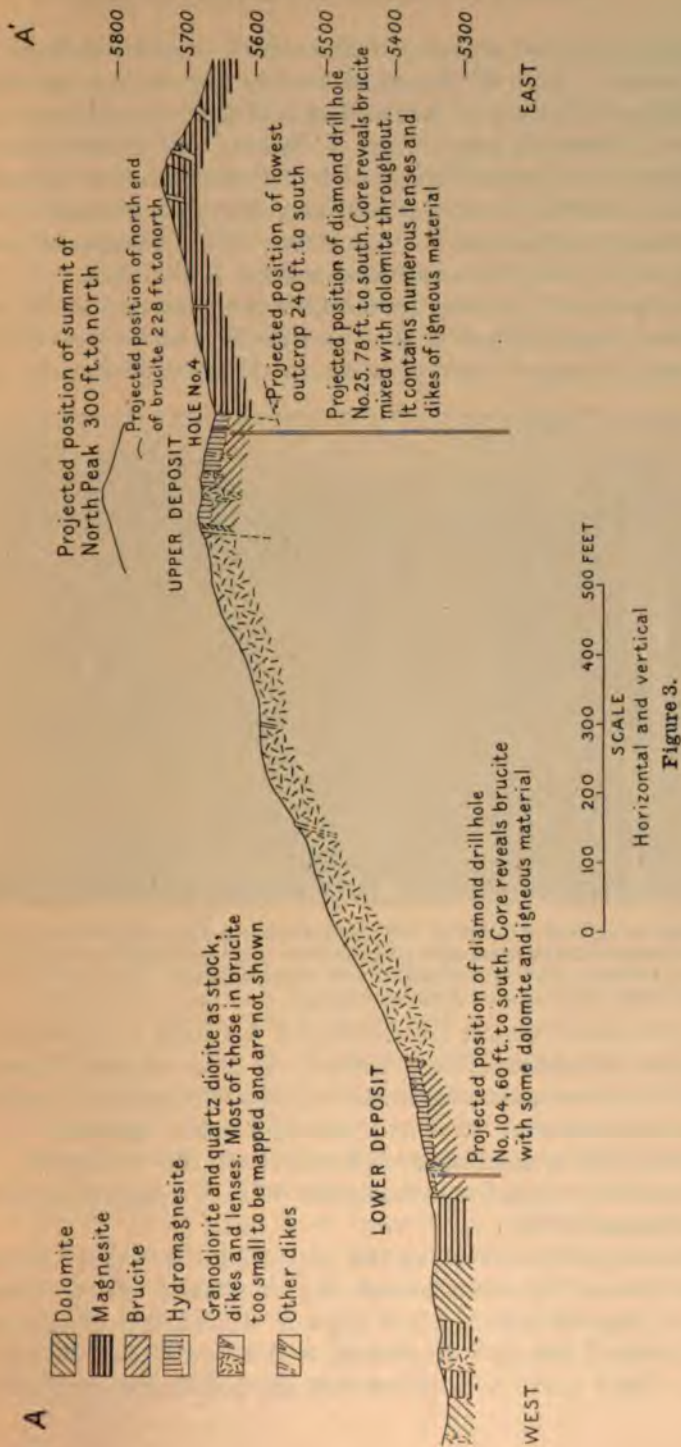
The numerous dikes and the northward prong of the granodiorite mass, as well as the brucite deposits, have a general westward trend. In the southwestern part of the area the strike is near N. 50° W., in the northwestern part near N. 30° W., in the northcentral part near N. 15° W., and in the eastern part N. 20° W. to N. 40° W. The trend of the axis of the eastern prong of the granodiorite is N. 30° W., and the direction of the contact near the north end of the upper deposit is near 60° to the west. The direction of dip of the dikes is generally but chiefly to the southwest at a steep angle.

THE DEPOSITS

BRUCITE

DISTRIBUTION—SIZE AND SHAPE OF BODIES

There are two masses of brucite of sufficient size to be mapped. In addition there are eight areas mainly less than 100 feet in diameter, in two of which brucite was proved to



whereas its original presence in the others is inferred from alteration products. One of the small masses lies on the northward prong of granodiorite 300 feet north of the center of Gloria Extension No. 3 claim. The other is on the east side of the granodiorite, east and southeast of the upper deposit of brucite. Another outcrop containing alteration products of brucite occurs near the granodiorite outside of but near the southwest corner of the area.

The smaller of the two main bodies which is known as the lower deposit (Figure 4) is located on the westward prong of granodiorite at the mutual



Figure 4. Lower deposit of brucite viewed from south. The deposit is underlain by brucite with granodiorite to the west (left), and dolomite (D) and magnesite (M) to the east (right), and hydromagnesite (B) to the south. Gabbs Valley and Fairview Peak in distance.

Gloria Extension, Gloria Extension No. 1, Gloria Extension No. 2, and Gloria Extension No. 3 claims. It is a rough rectangular area, 440 feet in maximum length and 250 feet in maximum width. The deposit is underlain by granodiorite on the north and east sides, magnesite on the west side, and magnesite and dolomite at the south. The exposed area occupies approximately 67,500 square feet on a horizontal plane.

The larger body, known as the upper deposit (Figure 5), is on the east side of the same prong of granodiorite, 800 feet north of the lower deposit and 250 feet higher. It consists of a north part 1,000 feet in length, and a south part 500 feet in length. Both parts are in line but are separated by a

nite 100 feet long. The maximum width of the north part 20 feet and the average width about 180 feet. The north is crossed by a gully towards which the surface slopes at on both sides. The area of the north part reduced to a horizontal plane is approximately 166,000 square feet, of which about 00 square feet lie north and 95,000 square feet lie south of transverse gully. The south part of the upper deposit lies saddle at the summit southeast of the north part. Its southmost 100 feet is very narrow, but the greater part is approximately 160 feet wide. The total area is approximately 43,000 re feet. Contacts are obscured in many places, especially



Figure 5. Southern half of upper deposit of brucite viewed from north- showing granodiorite (G) on west (right), and magnesite (M) and dolomite (D) on east. White material is hydromagnesite overlying brucite. The of dolomite that separates the long northern part from the short northern part of the deposit is just below the 5,900-foot summit.

with the granodiorite south of the gully so that the extent not be determined exactly. The areal measurements given to contacts as closely as they could be determined and do take into account igneous rocks or carbonate rocks within brucite deposits. It must also be pointed out that the areal of brucite is inferred from that of its oxidation products. Depos of brucite occur only in the gully in the upper deposit. A diamond drill has proved that brucite underlies the oxidation acts in the lower deposit and in the northern part of the deposit, but the existence of brucite has not been proved in the southern part of the upper deposit.

DEVELOPMENT

The discoverer prospected the deposits by means of which have an aggregate length of more than 100 feet approximately at right angles to the strike, and 10 feet deep on each of the deposits. The subsequent work consisted of prospecting both deposits by means of the diamond drill. Five holes were drilled in the lower deposit with an aggregate depth of 490 feet, the longest of them being 172 feet deep. In the main part of the upper deposit with an aggregate depth of 4,178 feet, the longest being 405 feet deep and 57 feet below the lowest outcrop. One hole, 57 feet deep, was drilled at the north end of the southern part of the

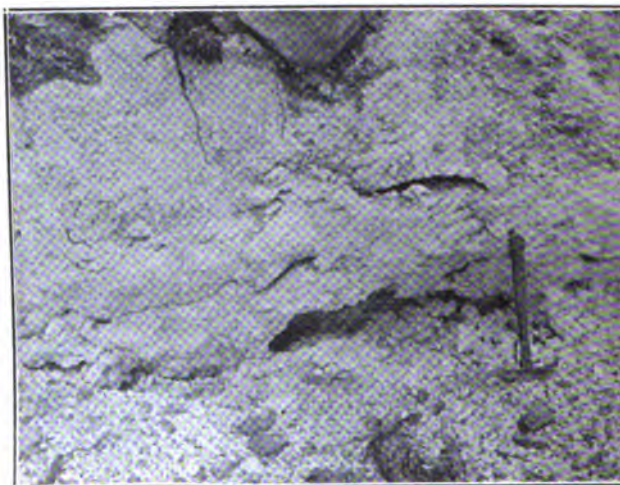


Figure 6. Shrinkage cracks in the oxidized covering of the upper deposit at diamond drill hole No. 9. Mostly hydromagnesite.

Nearly all the core made up of brucite and magnesite. A quarry was opened in the lower deposit. A quarry at a still lower level was cut through the brucite. The older quarry is approximately 30 to 45 feet long and 3 to 15 feet deep. The lower level, the proposed working level for both deposits, has a depth of 5,312 feet, is 80 feet long and 15 feet wide, and a depth of 25 feet. Plans for future development include the opening of a tunnel from the lower deposit through the brucite to the upper deposit, which should be reached below the surface and could then be mined by the open-pit method. Plans for treatment depend upon the uses found for brucite.

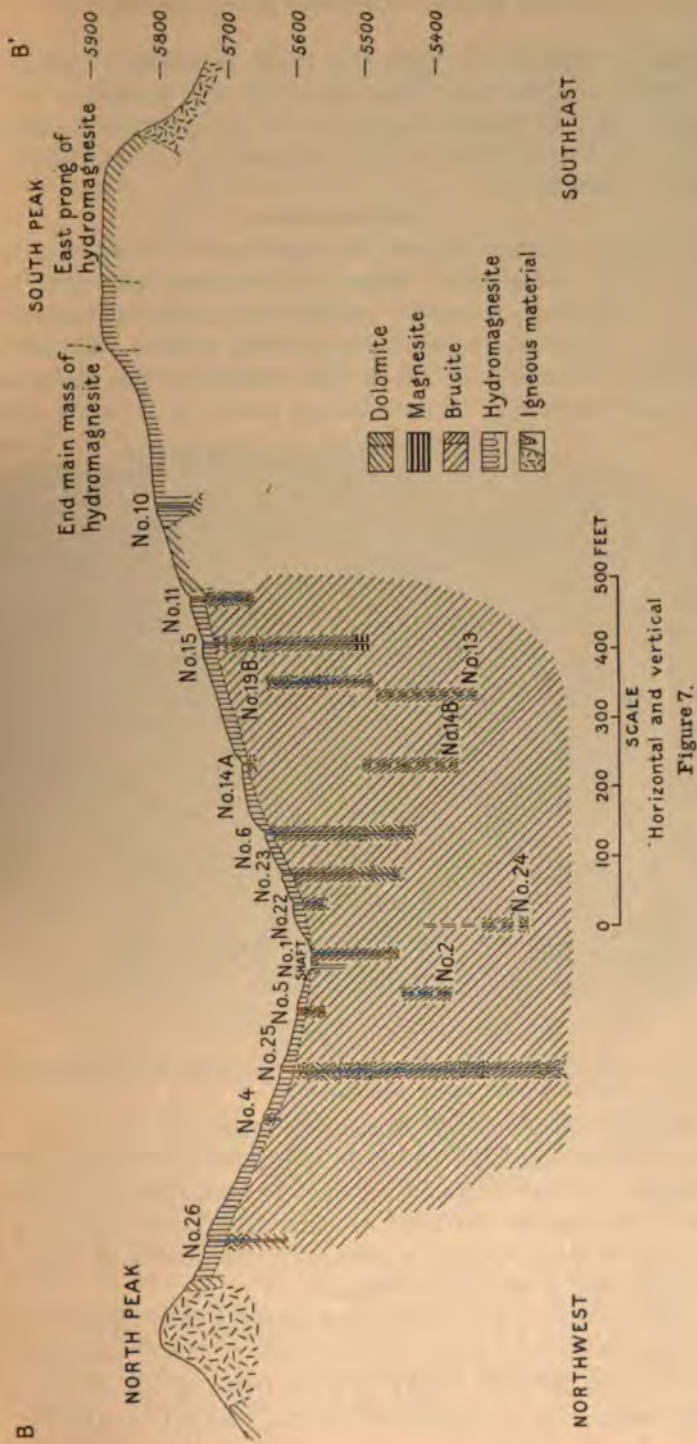


Figure 7.

A camp consisting of office, messhall, bunkhouse and four small cottages was constructed by the owner. A water system was put in, a pipe line laid from the cistern to the deposit, a road graded to the lower deposit and a black tank installed at that point.

COMPOSITION

The brucite (Figure 8) has the appearance of fine-grained laundry soap. The color ranges from white through various shades of yellow to a brown. Some specimens contain even black bands and some contain black specks. Translucent flakes of brucite occur in thin veinlets in the host rock. One specimen of a radiating group of crystals was found.



Figure 8. Fresh brucite from lower deposit showing the massive fibrous structure, and soapy appearance.

long direction of the crystal parallel to the c-axis was observed. Massive brucite will turn white on exposure to weather for a few months, but the coarsely crystalline material is not affected. Weathered surfaces of brucite are covered with a white bony coating which is generally cracked and does not show the underlying crystal structure (Figure 9).

The massive brucite consists of an aggregate of elongated crystals, distinguishable only under the microscope, that are 1 to 3 mm. in length. They are all oriented in the same direction at right angles to a coloration banding which is

everywhere present. The rock splits most readily parallel the elongation of the crystals. This elongation, which may be regarded as the grain of the rock, may continue straight for several feet or may be very complexly contorted. The quarry in the lower deposit reveals that the brucite may contain numerous intersecting slickensided surfaces whose directions are not controlled by any known structure and do not appear to conform to any system. Many of the diamond-drill cores reveal offsets in the banded structures in the brucite. These fractures have facilitated oxidation and removal of material so that open cavities are found in the diamond drill cores at the greatest depths attained.

Under the microscope pure brucite is nearly colorless. The cleavage is parallel to the long dimension of the grain. Under



Figure 9. Group of weathered boulders of brucite at upper deposit. Lower part shows veinlets of dolomite in brucite. The upper pieces show the characteristic weathered surface of pure brucite. Scale 6.8 inches long.

crossed nicols the brucite shows a peculiar brown interference color and reveals in some specimens numerous concentric fractures resembling perlitic structure in volcanic glass. Orientation is so uniform in some sections that the entire field darkens in unison under crossed nicols.

Impurities in the brucite are of fundamental importance so far as quarrying and treatment are concerned. They consist of carbonate minerals; contact minerals such as chlorites, garnet (rossularite), chondrodite, and apatite; and masses of intrusive igneous rocks. Though the last two groups are the most evident

and would appear to present the greatest problem. The presence of dolomite intimately mixed with much of much greater importance so far as the treatment of brucite is concerned. Under the microscope the dolomite is seen in some specimens as little rows of dots or as small grains of the brucite grains, as interstitial fillings and as small grains, and as numerous veinlets and larger masses. Figure 9. The presence of dolomite is indicated by the analysis of cores (Figure 10) by the increase in CaO as 0.29 per cent to more than 15 per cent. The presence of dolomite, which forms small grains and veinlets, presents a problem in the treatment of the material. The methods include separation of the finely-ground material by gravity or flotation, or by a process similar to that used in Argenteuil County, Quebec,⁴ which depends on the pinching temperatures of the constituent minerals.

The amount of inclosed contact minerals, chiefly magnetite, is approximately shown in the analyses by the percentage of Al_2O_3 . The percentage of Al_2O_3 commonly ranges between 1 and 2 per cent and exceeds 2 per cent in a few analyses of material near contact with igneous rocks. It averages about 1 per cent. Fe_2O_3 ranges from 0.40 per cent to 1.20 per cent and averages about 0.75 per cent. The amount of other troublesome flaky minerals is negligible. The oxidation products of brucite, chiefly if not wholly hydroxides, are in irregular, porous veinlets in the brucite down to depths attained by the drill, and form a blanket averaging between 10 and 15 feet in depth. Much of the magnesite contains some brucite, and residual brucite are common.

ESTIMATED RESERVES

Any estimates of the amount of brucite should take into consideration several factors including (1) irregularities below the surface, (2) possible pinching and faulting, (3) the amount of igneous material and (4) the amount of dolomite, (5) the amount of material, and (6) the amount of oxidation products at the surface, and the amount of cavities and oxidation products at depth.

It may be deduced from an examination of the material that an estimate may be made for brucite north of the surface for an average depth of 350 feet. The drill has reached brucite at that depth, but do not prove that

⁴Annual Report of the Quebec Bureau of Mines, 1929, p. 10.

deposit at that depth is the same as that at the surface. If, for the purposes of a rough estimate, it is assumed to be so, the deposit has a gross volume of 58,000,000 cubic feet, about one-third of which may consist of igneous material and carbonate rock. The northern part of the deposit contains numerous dikes which appear in the cores as well as on the surface. Though they make up a considerable part of the cores, the fact that their positions are more nearly vertical than horizontal gives an exaggerated idea of their quantity. It may be that more than one-third of the mass near the north end may not be brucite, but a smaller proportion of impurity may be expected in the southern part, and the above estimate therefore is reasonable. By using this estimate and the factor of 12.8 cubic feet per ton for brucite with some intermixed dolomite, the quantity of brucite present is calculated to be approximately 3,000,000 tons.

In the southern part of the upper deposit, beyond the dolomite barrier, the drill went through 50 feet of oxidized material to dolomite without striking brucite. Further exploration of this part should be made before estimates of reserves are attempted.

The lower deposit, as shown in Figure 3, has been explored by the diamond drill only at the southern and western sides. Brucite, according to one of the five drill holes, extends to a depth of 153 feet below the surface, but was found to contain many dikes and much dolomite; consequently, an assumed average depth of even 100 feet below the oxidized cover may be excessive as a basis for the estimation of reserves. However, if this depth is assumed and one-third of the volume of the deposit is assumed to consist of igneous material and other bulky impurities, the amount of brucite and intimately mixed dolomite is estimated to be approximately 348,000 tons. If oxidation has penetrated to an average depth of 12 feet, the estimated volume of oxidized material, including igneous rock, is approximately 310,000 cubic feet.

The amount of brucite in the small outlying areas is comparatively very slight, but no quantitative estimate of it can be made.

MAGNESITE

DISTRIBUTION—SIZE AND SHAPE OF BODIES

The distribution of magnesite was not determined for the whole of the area. In the field it is practically indistinguishable from certain varieties of recrystallized dolomite, and a systematic set of samples from the entire area of recrystallized rock must be collected and determined by optical or chemical methods before

HOLE 14 B UPPER DEPOSIT

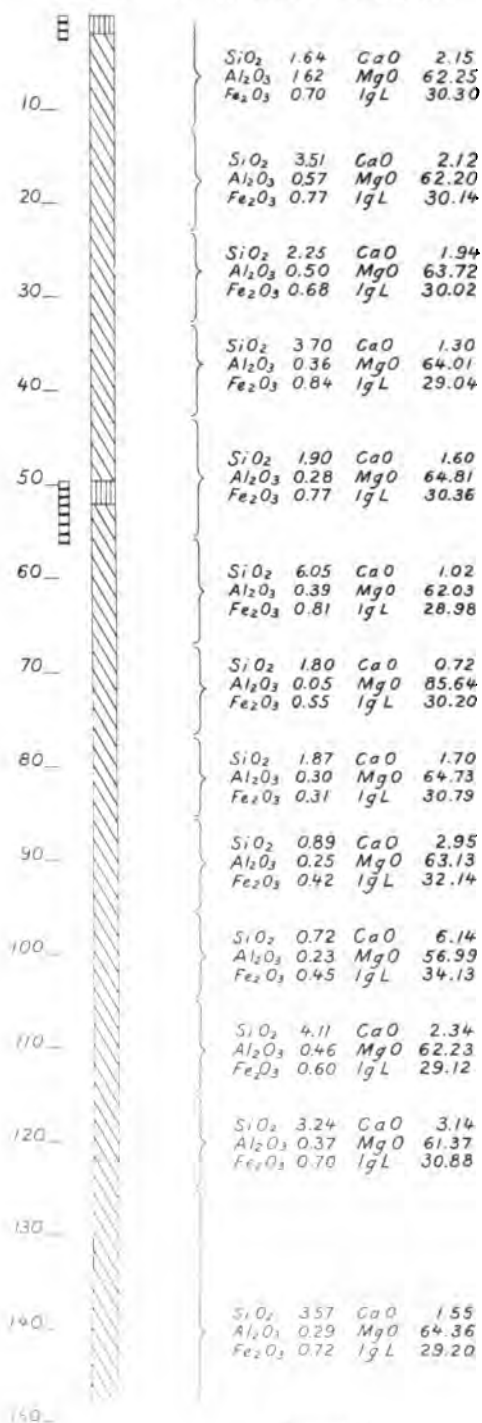


Figure 10.

HOLE 14 B (continued)

150_					
160_	Cavities and streaks of hydromagnesite	SiO ₂	2.29	CaO	2.05
		Al ₂ O ₃	0.28	MgO	64.51
		Fe ₂ O ₃	0.72	Ig L	29.97
170_	Light brucite hydromagnesite streaks	SiO ₂	1.65	CaO	2.34
		Al ₂ O ₃	0.43	MgO	63.00
		Fe ₂ O ₃	0.72	Ig L	31.30
	Dark brucite	SiO ₂	1.15	CaO	0.29
		Al ₂ O ₃	0.40	MgO	66.25
		Fe ₂ O ₃	1.34	Ig L	30.17
180_	Open cavities and hydromagnesite				
190_	Dark speckled brucite	SiO ₂	2.58	CaO	0.44
		Al ₂ O ₃	2.16	MgO	63.79
		Fe ₂ O ₃	1.34	Ig L	28.45
200_					
		SiO ₂	4.35	CaO	0.49
		Al ₂ O ₃	0.76	MgO	64.88
		Fe ₂ O ₃	1.22	Ig L	28.17
210_					
220_					
		SiO ₂	1.77	CaO	0.49
		Al ₂ O ₃	0.53	MgO	65.60
		Fe ₂ O ₃	1.05	Ig L	29.80
230_					
		SiO ₂	1.95	CaO	0.34
		Al ₂ O ₃	0.43	MgO	64.77
		Fe ₂ O ₃	0.77	Ig L	30.26
240_					
		SiO ₂	2.47	CaO	2.24
		Al ₂ O ₃	0.36	MgO	63.43
		Fe ₂ O ₃	1.15	Ig L	30.22
250_					
		SiO ₂	1.74	CaO	1.62
		Al ₂ O ₃	0.35	MgO	64.53
		Fe ₂ O ₃	0.84	Ig L	30.31
260_	Light brucite with a few streaks of dolomite	SiO ₂	0.88	CaO	1.19
		Al ₂ O ₃	0.31	MgO	64.59
		Fe ₂ O ₃	0.80	Ig L	31.63
270_					
	Brucite with oxidized streaks and some dolomite	SiO ₂	2.99	CaO	4.54
		Al ₂ O ₃	0.46	MgO	58.27
		Fe ₂ O ₃	0.70	Ig L	32.91
280_					
290_	Dolomite, brucite and serpentine	SiO ₂	4.12	CaO	16.89
		Al ₂ O ₃	0.48	MgO	39.20
		Fe ₂ O ₃	0.98	Ig L	38.28

Figure 10 (Continued).

the limits of magnesite can be established. The mineral tests made by the owners permitted its distribution in the vicinity of the lower deposit to be determined fairly. It occurs as a number of irregular lenses from 10 to 100 feet in length, with a maximum width of 150 feet, and is more variable in the outcrop because of a greater tendency to be stained and stained than the whiter more solid dolomite. A mass adjoins the brucite on the south and west. The lenses are traversed by granodiorite dikes as though they antedated the dikes. The surface area of the magnesite in the vicinity of the lower deposit is approximately 66,000 acres. There are a number of lenses of saccharoidal magnesite about 600 feet northwest of those just described. One of these is found to be dolomite and the others chiefly magnesite with considerable dolomite.

On account of the similarity of dolomite and magnesite it is not possible to distinguish them accurately in the laboratory tests of suites of specimens must be made. Specimens were collected in the area east and northeast of the lower deposit, and from these it is deduced that magnesite covers an area of more than 20 acres. Magnesite was found north of Tungsten Gulch over 1,900 feet north of the lower deposit and in the contact with the finely laminated dolomite south of the tungsten workings, 2,500 feet south of the lower deposit. There are large masses of dolomite with magnesite especially that surrounding the southern part of the lower deposit, that along the south sideline of the Blues. The large area including the Tungsten camp and the south. This appears to be a very large body of magnesite, but many specimens must be determined in the laboratory before a more accurate determination of the limits and amounts of magnesite may be made.

DEVELOPMENT

The presence of magnesite in the vicinity of the lower deposit was not recognized until after some of the diamonds had been analyzed. Consequently, not nearly so much was expended in prospecting magnesite as brucite. The pits that were dug in the vicinity of the lower deposit indicated the presence of magnesite and indicated the rock. Four diamond drill holes were put down in the north part of the upper deposit. These have reached a depth of 482 feet and the longest is 213 feet deep.

rilled in the brucite deposit near its east contact south of the transverse ravine, penetrates 250 feet of magnesite after going through 60 feet of brucite. The core revealed mixed dolomite and brucite in the lowermost 85 feet. The quarry at the lower deposit penetrates magnesite before reaching brucite.

COMPOSITION

Magnesite such as that exposed in the quarry at the lower deposit is identical with white marble in general appearance. Fresh material grades in color from white to dark gray. The dark material is more prevalent near the contact with the nearly black dolomite. The various shades of gray are due to finely divided carbonaceous matter. Weathered material is nearly always stained with iron oxide, though some may be white at the surface. In many places the weathered magnesite has a sugary appearance and disintegrates into sand. Gently sloping surfaces such as that east of the center of the upper deposit allow the sand to accumulate in considerable quantity. Some of the dolomite behaves in a similar manner, so that the general appearance does not serve as a reliable criterion for distinguishing the two minerals. The size of grain averages between 0.3 and 1.0 mm. A vein-like zone near Hole No. 27, east of the upper deposit, is much coarser grained, averaging from 5 to 10 mm. Some of the material is extremely fine grained.

The structure of most of the magnesite is massive. The crystals are equant and without definite orientation. Jointing is very irregular and not conspicuous. There is little or no indication of original structures. In some places, especially near the contact with unaltered dolomite, there are traces of replacement suggested by intersecting rows of relatively large magnesite grains between areas of fine-grained magnesite. Some of this material contains large crystals of dolomite. Some of the magnesite, notably that on the point east of the Tungsten cabins, contains alternate bands of light and dark crystals.

The impurities in magnesite consist mainly of igneous intrusive rocks, contact minerals, and dolomite. Brucite also occurs at several points. Small dikes and lenses of quartz diorite, granodiorite, and other intrusive rocks, however, are not nearly so numerous in magnesite as they are in brucite. Veins of serpentine appear at various points, but form only a small part of the whole. The most obnoxious impurity is dolomite. So far as could be determined from petrographic study the CaO shown by the chemical analyses represents grains of dolomite rather than

CaCO₃ in solid solution. Generally the amount found to be small and the CaO content under 2%. The average chemical composition of 36 feet of magnesite from Hole No. 27 is shown in column (a) in the table below. The composition of magnesite from 127 feet from Hole No. 28 is represented by column (b). The composition of magnesite from 68 feet below it by column (c). Column (d) represents the composition of Hole No. 16. Column (e) represents a general composition of magnesite in quarry at the lower deposit.

	(a)	(b)	(c)
SiO ₂	1.81	1.88	3.14
Al ₂ O ₃	0.62	0.73	1.43
Fe ₂ O ₃	0.57	0.40	0.38
CaO.....	1.46	8.87	2.09
MgO.....	46.85	39.96	45.78
Ignition loss.....	48.48	47.86	46.88
	99.79	99.70	99.70

Analyses by Abbot A. Hanks, Inc., San Francisco, Cal.

ESTIMATED RESERVES

Until the boundaries of the magnesite are determined, it is not possible to make more than a rough estimate. Theoretically, the amount of magnesite underlying the deposit to a depth of 100 feet would be 410,943 tons and, as the deposit is at least 20 acres, there may well be more than 400,000 tons including magnesite which may be too high in iron and other impurities for utilization. Both brucite and magnesite have been proved to exist at depths of more than 300 feet below the surface and very probably both may reach even greater depths. The magnesite adjacent to the lower deposit estimated to be 50 feet would amount to about 198,000 tons. The other lenses estimated to a depth of 50 feet would amount to approximately 53,000 tons. The others are small and probably not be exploited in view of the large reserves in the upper deposit.

FEATURES CONCERNED WITH ORIGIN

Since evidence regarding the origin of the brucite deposit is complex and in need of verification, and, further, since published conclusions on other deposits are divergent and somewhat conflicting, a thorough discussion of the subject is deferred until the final report. It may be said now that both brucite and magnesite have been deposited from solutions. This view is contrary to certain unpublished statements that the magnesite has been formed by desiccation of water, and therefore does not extend any appreciable

below groundwater level. Groundwater level is sufficiently deep, probably 800 feet, for a large deposit to form above it, but available evidence shows that the action of descending waters has been comparatively limited. The only mineral that gives clear evidence of deposition by descending waters is hydromagnesite. This mineral has a distinct relation to the present surface, and large masses of it on the whole do not extend downward more than 50 feet. At greater depth it is confined to fractures in the brucite, and therefore indicates that descending surface water has been an efficient alteration agent only close to the surface. The complete independence of the brucite and magnesite from such relations leaves little support for the suggestion that they could have been formed by descending surface waters.

No evidence of a limiting factor in depth of either brucite or magnesite has been found, but the deposits might be limited by a possible downward expansion of the granodiorite or change to dolomite.

OTHER MINERAL DEPOSITS IN THE VICINITY

A scheelite vein on the Betty O'Neal No. 1 claim was mined for tungsten during the war period. The scheelite occurs in lumps either with or without quartz in a gangue that consists principally of a peculiar soapy chlorite, identified as leuchtenbergite, with minor quantities of talc, white quartz, dolomite, magnesite, and limonite pseudomorphs after pyrite.

Two small lenses or pipes containing sulphides, chiefly sphalerite, lie east of the upper deposit on the Bluestone claim and that adjoining it on the north. Some chalcopyrite occurs disseminated in magnesite east of the upper deposit.

An assay of 0.16 oz. of gold was obtained over a width of six feet in a zone containing much iron oxide along the granodiorite contact west of the lower deposit.

ECONOMIC CONSIDERATIONS—USES OF BRUCITE AND MAGNESITE

As brucite has not been found in quantities sufficient to justify commercial exploitation elsewhere, no uses for the mineral have been developed. Brucite is reported to have passed successfully tests for use in petroleum refining. Some of the purest material might be suitable for carving if protected from weathering. It may be calcined and then must compete with magnesite and other magnesium minerals for refractories, plasters, pharmaceutical, and other products. It may possess some metallurgical advantages in the preparation of metallic magnesium other than the comparatively greater proportion of magnesium. Though much of the brucite contains impurities, these could probably be largely

removed by concentration, particularly as there is a difference between the specific gravities of brucite carbonate and silicate minerals.

The uses and production of magnesite and magnesium products are treated in various chapters of "Mineral Resources of the United States" published by the Geological Survey and the Bureau of Mines. Uses of magnesite in various forms listed include products such as bricks, shapes, and crucibles; artificial refractories for crucibles and furnaces; basic magnesium carbonate with asbestos for pipe coverings; cements and mortars; an absorbent in the manufacture of dynamite; an accelerator in the vulcanization of rubber; paint adulterant; in the manufacture of carbon dioxide or "dry ice" for refrigeration; in the process in paper manufacturing; and for metallic magnesium. In many of these uses it must compete with dolomite, magnesite stone and it has been displaced by magnesium chloride and metallic magnesium. The development of the brucite deposit depends largely upon the profitable development of the brucite.

SUGGESTIONS FOR FURTHER PROSPECTING FOR BRUCITE AND MAGNESITE

Massive brucite on fresh exposure may be recognized by its yellowish soapy appearance and its hardness, which is greater than that of talc and calcite. As brucite weathers, the deposits may be expected to be covered by a blanketing of porous hydromagnesite, as shown in Figure 6. Residual brucite may have the peculiar cracked bonelike appearance shown in Figure 9. The discovery of an area of soft white material or area of recrystallized carbonate rock, particularly in the presence of brucite, should be investigated.

The most rapid method for identifying magnesite is by its refractive index which so closely resembles dolomite, is the determination of its refractive index with the aid of index oils and the use of a microscope. Specimens should be sent to a laboratory where such an instrument and operator are available. A systematic collection of samples over the area will serve to outline the extent of the deposit. The more costly chemical analyses may be made later to determine the purity of the material. Experience in Washington leads to the conclusion that where a deposit of brucite is found magnesite may be expected to be found. The converse does not appear to be true, however.

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GEOLOGY OF THE TYBO DISTRICT, NEVADA

By HENRY G. FERGUSON
Geologist, U. S. Geological Survey

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IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY



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ABSTRACT

The Tybo lead-zinc district is situated on the eastern side of the Hot Creek Range in Nye County, Nevada.

The rocks include marine sediments of Cambrian, Ordovician, and Silurian age, two nonmarine formations of probable Tertiary age, and dikes and lava flows also regarded as Tertiary.

The Cambrian sediments have been mapped as three units. To these units new formation names (Swarbrick, Tybo, and Hales) have been given. The oldest, the Swarbrick formation, consists principally of chert and thin-bedded limestone and has an exposed thickness of 1,500 or 3,000 feet. Succeeding the Swarbrick is the Tybo shale, consisting dominantly of shale with a thickness of about 1,600 feet. The uppermost Cambrian unit, the Hales limestone, consists almost wholly of limestone. Its upper contact is not exposed, but a probable thickness of 3,000 feet is present.

The Ordovician and Silurian formations are lithologically similar to those of the Eureka district, and the same nomenclature is therefore employed.

The Pogonip is dominantly limestone, but near the top contains slate and quartzite members. Both lower Pogonip (Beekmantown) and upper Pogonip (Chazy) are present. No complete section was found, but it is estimated that no less than 500 feet of the lower Pogonip and 3,000 feet of the upper Pogonip are present.

The Eureka quartzite overlies the Pogonip limestone, but is lacking in places. Its maximum thickness does not exceed 150 feet.

The Ordovician limestone, which at Eureka overlies the Eureka quartzite, is lacking at Tybo, and the quartzite itself suffered erosion before the deposition of the Silurian. The Silurian consists of several hundred feet of massive dolomite with a little limestone near the base. The formation is lithologically similar to the Lone Mountain limestone of Eureka.

The Gilmore Gulch formation consists of sandstone, shale, and tuffaceous tuff. On lithologic evidence it is thought to be of Tertiary age.

The Gilmore Gulch and older formations are cut by numerous dikes of quartz latite porphyry, and at least 500 feet of similar quartzite, probably a flow, overlies the Gilmore Gulch formation.

After weathering and erosion of the rhyolite about 150 feet of dominantly tuffaceous sediments were laid down. These sediments are similar in character to those of the Esmeralda formation, of upper Pliocene age, and are herein designated Esmeralda (?) formation.

Overlying the Esmeralda (?) formation are flows of andesite, dacite, and rhyolite.

The structure of the district is complex. The Paleozoic central part of the area have been strongly folded, the folding trending a little north of west. The rocks are overturned to the south and southwest and is broken by a normal fault. The rocks to the south of this fault are relatively recent. The folding apparently did not involve the Gilmore and it is assumed that it took place within Mesozoic time.

Several stages of faulting are shown by relation of each other, to the dikes of quartz latite porphyry, and lavas. The oldest major fault, the 2 G-Dimick fault, is a limb of the overturned anticline and is considered to have formed at the time of folding. The displacement is in the north and may exceed 6,000 feet. Thrusting may have occurred along low angle faults in the eastern part of the district during the period of compression.

The first period of normal faulting was prior to the formation of the quartz latite porphyry dikes. The principal fault was later cut and displaced the earlier reverse fault, but the motion along the reverse fault. There was also motion along the quartz latite intrusion along both faults. Normal faults of the range front are later than the lavas that overlie the formation.

Although the faults along the range front are common, the present relief of the range is probably not directly due to the but to erosion of the less durable formations to the west.

The ores of the district were discovered in 1869 and have been continuously mined until 1879. Production since then has been intermittent. The recent period of activity began in 1929. The ore was made from oxidized ores rich in silver. The ore has been primarily valuable for lead and zinc, with some silver.

Practically all the ore so far mined has come from the 2 G fault, principally bodies that have replaced the quartz latite porphyry which follow the fault. The principal minerals are pyrite, sphalerite, galena, chalcopyrite, and arsenopyrite. Of these only galena and sphalerite are mined under present conditions. The galena is argentiferous. The principal minerals are chiefly fine-grained quartz and coarsely crystalline calcite. Manganiferous calcite is present in a few places in the district.

The oxidized minerals which were first mined extend to a depth of about 300 feet. Below this depth oxidation is less complete and the higher silver content of the sulphide ores in the upper part of the range as the presence of later pyrite and marcasite, suggesting that there has been some supergene sulphide enrichment.

The porphyry adjoining the ore is highly sericitized and has been replaced by calcite.

Ore deposition followed the intrusion of the porphyry and was later than movement along the fault that fractured the porphyry and permitted its replacement. The ore deposition probably took place at a comparatively shallow depth, probably a few hundred feet below the surface.

The district is believed to offer an expectation of considerable production at normal price levels. Although the ore may not reach great depths, there is a large area of promising but unexplored ground above the deepest level to which mining has extended, and other faults than the one on which development has been concentrated may prove worthy of exploration.



Figure 1—Map of Nevada showing location of

THE TYBO DISTRICT, NEVADA

By HENRY G. FERGUSON

INTRODUCTION

The Tybo district (Figs. 1 and 2) is situated in the Hot Creek Range in the northeastern part of Nye County, Nevada. The

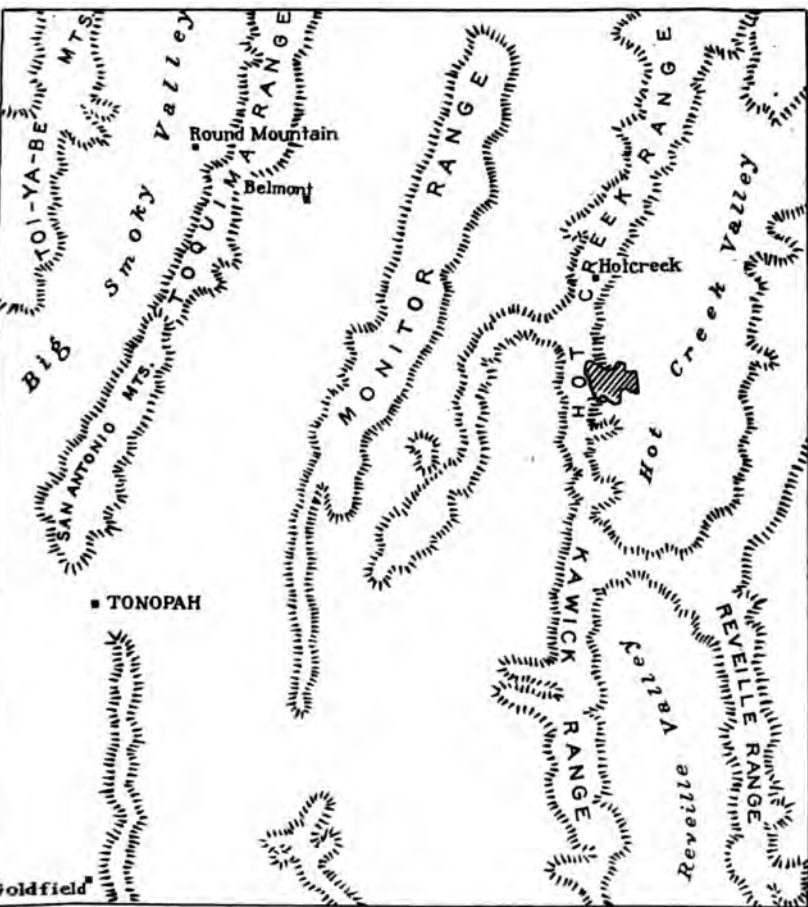


Figure 2—Map of area outlined in Figure 1, showing position of Tybo district.

mp is about 65 miles by road northeast of Tonopah, the nearest road point, and about 100 miles southwest of Ely.

The district was visited by the writer in the summer of 1929, and three weeks spent in a preliminary study of the geology. A second short visit was made in the summer of 1930. For a few

days during 1930 the writer was ably assisted in mapping by Siemon W. Muller. The writer gratefully acknowledges the assistance received from all those with whom he came in contact, particularly Messrs. W. H. Blackburn, G. H. M. Lewers, of the Treadwell-Yukon Co., Ltd., and J. W. Swarbrick, of the East Tybo Mining Co.

The camp and principal mines are in Tybo Canyon, which drains eastward to the Hot Creek Valley. At the camp, eastward from the camp to the front of the range are steep walls, which rise to heights of over 1,000 feet above the canyon floor. Westward the canyon opens out into a broad valley with gently sloping walls. The east front of the canyon is with steep slopes in the interstream areas, but westward there is a gradual slope from the crest to the valley floor.

The lowest point in the area mapped, on the front of the range, is about $1\frac{1}{2}$ miles south of the mouth of Tybo Canyon, at an altitude of about 6,200 feet¹ above sea level. The highest point on the ridge, north of the canyon, exceeds 8,400 feet above sea level.

There is no permanent natural surface flow in Tybo Canyon. An adequate water supply for the camp is obtained from a spring in the open part of the valley, and the water from the spring is ample for milling.

The topographic map, which serves as a basis for the geologic map (Plate 1), was made by reconnaissance methods. It is therefore only approximately accurate. The base used for the map is the surface plant of the Treadwell-Yukon Co. The elevations of various points, such as shafts and houses, were plotted on a reduced scale on the plane-table. The map, with these positions, which were included in an area of 3,000 by 1,000 feet, as a base, intersections were made with a Gurley compass as alidade, on a sufficient number of points to serve as controls for topographic sketching. The error increases outward from the base, but within the area bordering Tybo Canyon within a mile of the Tybo Canyon the probable error of position does not exceed 200 or 300 feet. In the outer portion of the area the error may be much larger. The elevations were determined by aneroid barometer, and though never possible the error may be of the same order. The datum used was the altitude of 6,700 feet above sea level given on the maps of the Treadwell-Yukon Co. for the 2 G shaft.

¹All altitudes given in this report are based on aneroid readings.

ROCK FORMATIONS

SUMMARY

The rocks of the Tybo district include sediments of early Paleozoic age, from Cambrian to Silurian, a sedimentary formation of unknown age, possibly Tertiary, and dikes, lava flows, and sediments of probable Tertiary age. The Paleozoic formations have been closely folded and extensively faulted, but the younger formations, though tilted and faulted, are not folded.

CAMBRIAN

The Cambrian of the Tybo district was divided on a lithologic



Figure 3—Chert and thin bedded limestone, Swarbrick formation.

basis into three units, to which, as they were not closely comparable with the nearest known section, that of the Eureka district, local names have been given.

Swarbrick formation — The Swarbrick formation derives its name from the Swarbrick prospect, in the eastern part of the district, where it forms the hanging wall of the ore-bearing fissure. The formation crops out only in the eastern part of the district,

where an anticline gives an elliptical area of outcrop about 100 feet wide along the creek, truncated on the south by the 2 G fault and extending northward from the 2 G fault for about 1 mile. The base of the formation is not present, and in the area where there is much minor folding and crumpling (Fig. 3) it is impossible to make any close estimate of thickness. However, a thickness of 3,000 feet is probably exposed.

The formation consists in large part of gray cherty limestone. The chert bands do not exceed a few inches in thickness. The limestone with the chert is a varying amount of bluish-gray. The chert is in thin bands. The limestone appears to increase in thickness toward the top of the formation, and at the Swarbrick up to the crest of the anticline the limestone exceeds 100 feet in thickness. Near the top of the formation, shale is interbedded with the chert, and the contact with the overlying Tybo formation is transitional. The uppermost chert beds were included in the Swarbrick formation, and thus, as mapped, the uppermost 100 feet is in places dominantly shale, containing more limestone.

The formation is prevailingly thin-bedded, and in the area in which it crops out is consequently much less prominent than the Ordovician limestones. On the other hand, it is much more resistant than the shales of the Tybo formation, which underlie it; consequently there is a marked step in the canyon walls within the area occupied by this formation.

Tybo shale—The Tybo shale, named for its exposure in Tybo Canyon near the camp of Tybo, consists dominantly of olive-gray to dark shale. The lithologic difference between the basal part of the Tybo formation and the underlying Hales formation are not sharp. For purposes of mapping the top of the highest chert bed of the Tybo formation is taken as the top of the highest chert bed of the Hales formation. Thin beds of limestone and calcareous shales and concretions of dense gray limestone appear near the top of the Tybo formation, and the transition between shale and limestone in the thin-bedded limestone of the Hales formation is much sharper than the transition at the base of the Tybo formation.

The exposures are not as good as those of the Ordovician limestones and as the shales are much crumpled no close estimate of thickness is possible. As measured across the strike of the formation on the basis of average dips observed and estimated for the underlying and overlying formations it appears probable that the total thickness is about 1,600 feet.

The principal area in which the formation is exposed is a belt between 1,000 and 3,000 feet wide bordering the Swarbrick formation north of the 2 G fault, principally north of the canyon. In the eastern part, near the mouth of the canyon, the apparent thickness is probably increased through partial repetition by faulting along the extension of the northerly fault that borders the hills south of the canyon.

The same formation also crops out south of the canyon in the lowland bordering the range between the range front and the valley fill.

As the Tybo shale is less resistant than the overlying limestone and underlying chert, it tends to form lowland areas. On the north side of the canyon it crops out in an area of gentle slope, largely covered by talus of limestone. South of the canyon the formation is repeated by faulting. The northward-trending canyon that enters Tybo Canyon near its mouth is cut along one belt, and the other occupies the pediment bordering the upland area.

Hales limestone—The uppermost Cambrian formation is here named Hales limestone from the Hales shaft of the Tybo mine, which is almost entirely within this formation. The formation consists almost entirely of limestone. At the base there is about 50 feet of brown shaly limestone transitional from the underlying calcareous shale of the upper part of the Tybo formation. In places, however, as in the areas near the east front of the range, these transitional beds are missing, and the fissile shale of the Tybo lies directly below the limestone. It may be, however, that the absence of the transitional beds is due to faulting.

The formation consists chiefly of bluish-gray limestone, for the most part thin bedded but containing a few massive members. Lenses and nodules of dark chert are abundant near the base but are absent from the upper part of the formation.

The upper part of the formation, as mapped, contains one or more beds of quartzite. On the north slope of the ridge north of the canyon, about 2,500 feet above the base of the formation, a bed about 200 feet thick is present. Three quartzite beds, each about 50 feet thick, were found in the block adjoining the Uncle Sam fault in the northern part of the district, but here the interpretation of the structure is uncertain, and it may be that a single bed is repeated by folding or faulting. As the quartzite occurs above the horizon at which Cambrian fossils are present it may possibly belong to the overlying Pogonip limestone, perhaps marking the base. However, as its relation to the undoubted Pogonip

is unknown and the lithology of the limestone is thin-bedded and below, it is included on the map with the Hales formation.

As the Hales is lithologically similar to the overlying limestone, and as no single block of the fault-block district contains both Cambrian and Ordovician formations, the position of the upper boundary could not be determined. The entire thickness of thin-bedded gray limestone block north of the 2 G fault and east of the Uncle Sam fault is assumed to belong to the Hales formation, giving a thickness of about 3,000 feet. The thickness from the highest bed in which Cambrian fossils were found is about 1,000 feet.

The principal area of outcrop of the Hales limestone is north of the 2 G fault, bordering the area of the Tybo shale. Where more resistant it forms an upland around the more resistant shale. On the west, where the dips are generally steep, the Hales formation crops out in a ridge between the Tybo formation and the Uncle Sam fault. On the north the gently dipping Hales formation forms the prominent cliff-walled ridge that forms the Tybo Canyon. The formation is not continuous on the west limb of the anticline, as it is broken by the fault. On the east limb, the front of the range, but it forms the crest and the top of the ridge facing the valley south of the canyon and is present on the corresponding ridge north of the canyon.

Dr. Charles E. Resser reported as follows on the fossils collected from the Hales formation:

Lot 30.73 contains a new species of *Pterocephalia*, with some smaller trilobites indicates the same formation that occurs in the Eureka district, but unfortunately it is not placeable in any determined section. At present it is placed as situated either in the upper part of the Secret Canyon or a little higher in the section. Lot 30.72, which you saw, contains trilobites that are altogether new. The rock material appears to be approximately the same, but the trilobite material that is present is not confined to any particular horizon, but is widely throughout the Upper Cambrian. However, since I have been able to uncover would place this material in the same horizon as the preceding lot, making all of it Upper Cambrian.

ORDOVICIAN

Two formations of the Ordovician section of the Tybo district, the Pogonip limestone and the Eureka quartzite are present in the Tybo district, but no Ordovician formations are present. The Eureka quartzite is present, and the Eureka quartzite to a minor extent the underlying Pogonip limestone.

been eroded before the deposition of the next higher formation, the Lone Mountain dolomite, of Silurian age.

Pogonip limestone—As fossils characteristic of the Pogonip formation, which is widespread over eastern Nevada, were found at many different horizons below the Eureka quartzite, the accepted name is used in the description of this formation.

Both the lower Pogonip (of Beekmantown age) and the upper Pogonip (of Chazyan age) are present in the district, but as no certain dividing line could be established they are not separated on the geologic map.

The rock occupying the wedge between the two eastern branches of the 2 G fault contains fossils of lower Pogonip age. Here the rock consists almost entirely of blue-gray limestone with well-marked bedding planes from 6 inches to 5 feet apart. A thin bed of quartzite, apparently not continuous, crops out near the northern branch of the fault in about the middle of the exposed section. The thickness of the formation, as exposed between the two branches of the 2 G fault, is at least 500 feet. Fossils from this locality were identified by Dr. Edwin Kirk as *Orthis* sp. and *Lingulella* sp.

Fossils of lower Pogonip age were also collected at the south end of the ridge just north of the mouth of the canyon. Here the relations with the neighboring rocks are uncertain. The gray limestone containing the Ordovician fossils is in fault contact with shaly limestone similar to that which crops out elsewhere at the base of the Hales formation and which carries Cambrian fossils. The north end of the ridge is capped by quartzite lithologically similar to the Eureka, but the ridge is crossed by one or more faults.

Dr. Kirk identified the following fossils from this locality:

29-99. Base of limestone at mouth of Tybo Gulch, north of gulch.

Lingulella cf. *L. pogonipensis* (Walcott).

Orthis sp.

Cystid plates.

Fragments of asaphoid trilobite.

Annelid trails.

Fossils of upper Pogonip age were found within a much larger territory, but it is possible that in these areas there may also be lower Pogonip beds, or there may be a gap of unknown extent between the recognized upper and lower Pogonip exposures.

The thickest section exposed is in the area north of the Dimick fault and west of the 2 G fault. Here the lower portion, exposed

on Air Shaft Ridge and in the lower part of Bu consists of about 1,000 feet of medium to thin limestone that weathers to smooth surfaces of l this is a bed of impure quartzite, conglomeratic nowhere over 50 feet thick. This bed can be south side of Air Shaft Ridge to a point a short the Bunker Hill fault, but is not found farther feet of thin-bedded limestone overlies the qua limestone is a persistent zone of shale 400 feet shale is in part brown and calcareous, but p north, near the head of Bunker Hill Canyon, ceous, with red iron oxide staining on the par 1,000 feet of limestone that overlies the shale bedded than the lower limestone members. In the 2 G fault the limestone at this horizon form above the bench cut on the shale, but north of where the dips are generally steep, the more tend to form sharp ridges. At this horizon the least one bed of dolomite, apparently continuous of the sporadic dolomitization found in places Just beneath the Eureka quartzite a little spl was seen in places. This bed is probably not and is rarely observable, owing to the heavy ta lying quartzite. The total thickness of Pogon the area north of the Dimick fault is about 3,0 south of the 2 G fault and east of the Uncle Sa same general lithologic sequence, though, perh in location on the topographic map, the appare different members is not quite the same. From of the Tybo mine to the crest of the ridge the the beds exposed is about 2,200 feet.

The principal fossil collections from the Pogonip came from the ridge south of the 2 identified the following fossils from collections southeast of the Tybo mine. Of these the first lected from the limestone below the shale an ately above it.

29-18.

Orthis sp.

Orthis type of *O. tricenaria* Conrad.

Rafinesquina sp.

Maclurites sp.

Cameroceeras sp.

- 29-19. About 100 feet above 29-18.
Receptaculites mammillaris Newberry.
Maclurites sp.
Illaenus sp.
Small subspherical algae (?).
29-20. Overlying slate.
Indeterminable bryozoan.
Orthis cf. O. lonensis Walcott.
Orthis type of O. tricenaria Conrad.
Calcareous algae (?).

Collections made south of the 2 G fault on the east front of the range yielded the following:

- 29-103.
Indeterminable bryozoan.
Valcourea (?) sp.
Liospira sp.
Trochonema sp.
Leperditia bivia White.
30-101.
Undescribed bryozoan.
Orthis sp.
Eotomaria sp.
Maclurea sp.
Leperditia bivia White.

Dr. Kirk comments as follows on the upper Pogonip collections:

The foregoing lots may be correlated with the Chazyan of the East. The horizon is not known in Colorado or Texas, but an approximately equivalent horizon is found in the Swan Peak of northern Utah. Equivalent horizons are found in British Columbia.

Fossils of upper Pogonip age were also found on Air Shaft Ridge and the hill to the north, but in this area they are poorly preserved.

Eureka quartzite—The Eureka quartzite, characteristically a dense white quartzite, overlies the Pogonip limestone. In a few places where cementation is not complete, generally near the base, it is grayish in color, and faint bedding and rarely cross-bedding can be distinguished. It differs from the thin quartzite beds within the Pogonip formation in being purer and more massive.

As no fossils were found in the formation, the correlation with the standard Eureka section is based on its lithologic character and stratigraphic position. Where it lies between the Pogonip limestone and Lone Mountain dolomite, as in the hills west of the Bunker Hill fault, its position together with its lithologic character serve to distinguish it with certainty. In the eastern part of the district the overlying Lone Mountain dolomite is eroded, and

the quartzite occurs as isolated masses capping limestone. Its nearly pure-white color, greater tation, and greater thickness serve to distinguish quartzite within the Pogonip limestone. Two masses of what is believed on lithologic evidence quartzite occur along the Bunker Hill fault near Tybo Canyon.

The maximum thickness as exposed in the area is only about 150 feet. On the hills north of the district the Eureka is present as a series of discordances of unequal thickness, the result of erosion prior to the deposition of the overlying Lone Mountain dolomite.

SILURIAN

Lone Mountain dolomite—Above the Eureka limestone in the western part of the district is a thick formation consisting of several hundred feet of massive dolomite with some chert at the base, which is correlated with that part of the Pogonip limestone of the Eureka district which is younger than of Ordovician age.

The formation is readily distinguishable from the Pogonip limestone by its more massive appearance and its characteristically rough surface. Well-defined bedding is especially in the dolomitic portion. Dolomite is the main part of the formation, in contrast to the dominant limestone of the underlying Pogonip limestone. There is, however, a thin bed of dark limestone near the base and, as noted above, in places a little dolomite, apparently unconnected with the upper part of the Pogonip limestone.

The western part of the hill north of Tybo Canyon, where the Bunker Hill fault contains the principal exposure of the formation. Here it rests for the most part on the weathered surface of the Eureka quartzite and, where the fault is directly on the Pogonip limestone. At the base of the formation is of variable thickness, generally not over 100 feet, more massive than the underlying Pogonip limestone and with a rough surface, and above this is massive dolomite, light-colored and characteristically weathering to a rough irregular surface. In places the dolomite contains white chert.

Massive dolomite, which is considered to be the main part of the formation, although the underlying Eureka quartzite crops out in the triangular area bounded by the Bunker Hill and Uncle Sam faults.

The only determinable fossils from this formation were obtained from the dark limestone near the base of the formation a short distance north of the Cunningham prospect. Dr. Edwin Kirk reports on them as follows:

This lot is of middle Silurian age.

Conchidium sp.

Plectatrypa? sp.

Coenites sp.

Pachypora sp.

Striatopora sp.

In the Eureka district the limestone directly overlying the Eureka quartzite is of Ordovician age. This limestone is absent in the Tybo district. As the Eureka quartzite was eroded prior to the deposition of the Silurian limestone, it may be that post-Eureka Ordovician limestone, if deposited in this area, was removed during this period of erosion.

TERTIARY (?)

Gilmore Gulch formation—The Gilmore Gulch formation, named from its exposures in Gilmore Gulch, consists of sandstone, dark shale, and siliceous tuff. It occupies a low-lying area in the southern part of the district. The rocks are less resistant than others of the region, and the area in which they crop out is largely covered by talus from the quartz latite hill on the west and the cliffs of Pogonip limestone on the east; consequently exposures are poor.

The base of the formation is not exposed; the probable thickness of the exposed portion between the Uncle Sam fault and the rhyolite to the west is 400 to 500 feet.

The area in which the Gilmore Gulch formation is exposed is separated from the older formations on the north and east by faults. On the west the formation is overlain by a thick flow of quartz latite. No indication of its age is therefore evident from the areal geology other than the fact that the structural relations indicate that it is younger than the Lone Mountain dolomite and older than the thick series of dominantly volcanic rocks that overlie it.

In the neighborhood of the Eureka district, particularly in the area shown on the Roberts Mountain topographic map, west and northwest of Eureka, there is an undescribed formation of probable Carboniferous age consisting dominantly of dark shale and sandstone and containing at least one flow of a basic amygdaloidal lava. It was at first supposed that the Gilmore Gulch formation of the Tybo district was the equivalent of this formation, and

specimens of the shales contain possible fossil remains that suggest fragments of *Stigmaria*.

Field work in 1930 threw doubt on the probable age. Except near the Uncle Sam fault the rocks are more dense and compact than the Paleozoic formations. When additional outcrops were studied it was seen that they were derived from siliceous igneous rocks, constituting a part of the formation, and that these tuffs show a composition more consistent with a Tertiary than a Cretaceous. The tuffs and lavas of Triassic and Jurassic age are a part of the Tonopah quadrangle, 60 miles to the west, and have been altered. In the southern part of the Tybo district, in the area shown on the map, there was found a flow of granite or dacite, similar in general appearance to the granite overlying the Gilmore Gulch formation. This flow is interbedded with the sediments of the formation and is covered by a few feet of sandstone before the base of the granite flow is reached.

The observations obtainable on the attitude of the rocks show that although dips are steep close to the Uncle Sam fault, to drag on the fault, there are apparently no folds in the formation, and the attitude of the higher beds is that of the base of the overlying lava. However, the rocks just east of the Uncle Sam fault likewise show tilting.

The Tonopah formation of the Tonopah district consists of at least 1,000 feet of largely water-laid material at the base of the Esmeralda formation. Although it is more massive than the Gilmore Gulch formation, its presence in approximately the same stratigraphic position is perhaps additional evidence for a possible Tertiary age of the Gilmore Gulch formation. The Tertiary deposits of the Elko region consist of the Chaney,³ a flora indicating a middle Miocene age. It is therefore thought that, notwithstanding the absence of evidence in the Tybo district, an early Tertiary (upper Miocene) is not unlikely.

TERTIARY

Rocks to which a Tertiary age can be rather definitely assigned, although no fossils were found in them, occur in

²Nolan, T. B., The underground geology of the western Nevada mining district, Nevada: Nevada Univ. Bull., vol. 24, pp. 10-11.

³Chaney, R. W., personal communication.

of the district and cover the western slope of the range. These rocks are dominantly volcanic flows but also include sediments, and rocks of identical lithologic character occur in places along the eastern front of the range, east of the faults that parallel the range front. Porphyritic dikes similar in composition to the oldest of the flows are intrusive into the older sediments, particularly along the faults. Although there is no essential difference in composition between these dikes and the quartz latite flow, it is convenient to emphasize the difference in geologic occurrence by retaining the local distinction implied by the term "porphyry" and referring to the dikes as quartz latite porphyry and the effusive rock as quartz latite.

Quartz latite porphyry—A large number of small masses of porphyry occur throughout the area covered by the older formations. For the most part these masses have been intruded along preexisting fault planes, but in the relatively weak and thin-bedded shale of the Tybo formation there are numerous small sills parallel to the bedding. Small dikes that are not related to known faults are also found in the Pogonip limestone, particularly in areas where it has been strongly folded. The more massive Lone Mountain dolomite is free from porphyry, except along the faults at its boundaries.

The greater number of the dikes are alike in texture and composition, and nearly all show more or less hydrothermal alteration. The rock is white and fine grained and carries abundant small quartz phenocrysts. In a few places, as in one of the dikes north of the Bunker Hill shaft and on the 800-foot level of the Tybo mine, there is a well-marked banding parallel to the walls.

In most of the dikes the only readily recognizable mineral is quartz, which occurs in phenocrysts as much as 3 millimeters in diameter, for the most part deeply embayed by the matrix. Close inspection usually reveals also feldspar and a little bleached biotite. Study under the microscope shows that oligoclase, about Ab_{80} in composition, generally in part replaced by calcite and sericite, forms most of the small phenocrysts and much of the feldspar in the groundmass. Phenocrysts of orthoclase, similarly altered, and also present, and in some specimens the amount of orthoclase exceeds that of the oligoclase. Biotite is sparingly present and is inconspicuous. It is commonly altered to chlorite or sericite or a mixture of both minerals. The groundmass consists of a very fine grained aggregate of quartz and feldspar, the individual grains ranging from 0.02 to 0.05 millimeter. In one or

two of the thin sections examined the groundmass developed spherulitic texture.

A few dikes similar in general composition and texture are cut by large feldspar phenocrysts. Some show oligoclase as much as two centimeters in length, sparsely scattered in the rock. Others show more abundant smaller phenocrysts of feldspar three millimeters or less in length and some contain phenocrysts of quartz. The smaller feldspars are mostly microcline. Biotite, largely altered to chlorite and sericite, is present in rare small phenocrysts. Dikes of this variety are common and are noted in the Tybo mine near the 2 G shaft and on the Bunker Hill shaft. The relative age of the dikes is not determined.

There is no perceptible metamorphism of the sediments adjacent to the dikes other than a slight induration of the shale of the Gilmore Gulch formation, but near the peak, on the east front of the range, south of the Tybo Canyon fault, is a small area in which the gently tilted limestone of the Pogonip has been altered to finely crystalline white marble. The igneous rocks crop out in the immediate vicinity, and the altered area may be the result of contact metamorphism of the underlying intrusive.

Quartz latite—A large mass of quartz latite is located on the peak west of the Uncle Sam fault and south of the Tybo Canyon fault and crops out over a considerable area west, south and east of this peak. Similar quartz latite is also found along the base of the range, south of Tybo Canyon and east of the Tybo Canyon fault. In the principal area the lava shows flow banding at its base. This flow banding has approximately the same strike as the underlying Gilmore Gulch formation. In the principal area of the peak there is marked columnar jointing.

The upper part directly below the overlying sediments is highly weathered, as if it had been long exposed prior to the deposition of the later (Esmeralda ?) sediments. In the lower part the iron of the biotite is largely replaced by hematite together with oxidation of probable pyrite, gives the rock a rusty dish outcrops.

The total thickness of the quartz latite exceeds 100 feet.

The flow banding at the base and the presence of the quartz latite in two widely separated parts of the district indicate that the rock is a flow, but it might also be interpreted as a massive mass from which the cover was removed by erosion and the deposition of the later sediments.

The quartz latite does not differ essentially from the porphyry dikes just described. The grain is finer, and the phenocrysts are generally smaller and less prominent, though in places they form a greater proportion of the rock than in the dikes. Biotite appears to be much more abundant in the rhyolite than in the dikes. This abundance is in part due to its generally less complete alteration. Quartz is present in small embayed phenocrysts not exceeding two millimeters in diameter and generally less than one millimeter. Feldspar phenocrysts are of the same size and equal abundance. As in the dikes, oligoclase and orthoclase are both present; their relative abundance is uncertain, but oligoclase is apparently more abundant than orthoclase.

In general the groundmass is more minutely crystalline than that of the dikes, spherulitic texture is much more common, and glass is present in specimens collected near the base of the flow.

The close petrologic similarity of the flow to the porphyry dikes suggests that they are essentially contemporaneous and that the dikes may represent conduits through which the lava passed to the surface. The apparent difference between the two rocks is largely due to the greater abundance of biotite in the quartz latite and its comparative lack of alteration.

Esmeralda (?) formation—Resting on the quartz latite mass just described is a series of light-colored water-laid sediments, dominantly tuffaceous. At the base is a conglomerate containing pebbles of rhyolite. Nothing was found to indicate the age of these sediments, but they resemble the Esmeralda formation, of upper Miocene age, which is present in the Manhattan district, 50 miles to the west, and at Tonopah, 65 miles to the southwest, and as this formation is widespread over central and western Nevada it is thought that the correlation is justified, although confirmatory fossil evidence is lacking. Similar sediments also overlie the quartz latite on the east front of the range, south of Tybo Canyon. As they are younger than the quartz latite, they are believed to be also younger than the mineralization. The faults in the western part of the district do not cut these sediments or the overlying lavas, but they are cut by the faults that parallel the east front of the range.

The maximum thickness in the western area is about 150 feet, but the formation appears to thin out to the south, as if deposited on an uneven surface of the quartz latite, so that on the high ridge a mile south of the mapped area and in the hills north of the area andesite appears to rest directly on the quartz latite.

Andesite and dacite—Above the youngest Esmeralda formation?) lies a series of andesite and dacite flows of several hundred feet in thickness. These flows differ in texture and composition in different places and were studied in detail. At one point, close to the power-line station, a series of lava flows is broken by a bed of white tuff. A crop of similar tuff, showing a steep dip, was found at the southeast corner of the area mapped, near the front of the eastern front of the range. The dip of the tuff in the western part of the district is less than that of the Esmeralda (?) formation, indicating an unconformity.

Rhyolite—On the west edge of the district the contact is formed by a thick flow of rhyolite. This rhyolite shows flow structure at the base and columnar jointing in the upper part. As far as could be seen from the road, this rhyolite forms the west slope of the range.

STRUCTURE

SUMMARY

The structure of the Tybo district is complex, and the writer is by no means satisfied that in the short time available he has been able to make an adequate explanation of all that has been observed. The most significant dips of the beds studied in detail are shown on the geologic map (fig. 1). An attempt was made to work out minor details of the structure. From the available data, however, it is believed that the interpretation of the structural history of the district is as follows:

In the area surrounding the district the Paleozoic rocks are relatively undisturbed, but within the district they are folded in a narrow zone having a general northwest-southeast trend. In places the principal fold was overturned to the southeast. The first faulting took place within and consequent upon the folding. The overturned fold and was presumably the result of reverse motion. The steeply dipping reverse fault was thus formed. Thrust faulting within the area of folding may have taken place at this time also. Later normal faulting took place during the same period. The old fault was cut and displaced by younger faults, but there was also later movement on the old fault in the reverse direction.

FOLDING

As far as known the Paleozoic rocks elsewhere in the Tybo Range, though faulted and tilted, are not highly

sharp fold of the Tybo district appears to be a local feature. Even within the district pronounced folding is confined to that portion north of the 2 G and Dimick faults and south of the high ridge that lies north of Tybo Canyon. This folding has produced an irregular anticline.

As outlined along the upper boundary of the lowest Cambrian formation, the Swarbrick, the axis of the central part of the anticline, trends north and south. The beds present steep dips and in places both limbs in the southern portion are overturned. Within the area of the Swarbrick formation the rocks are locally much contorted and show sharp subordinate folds. As outlined by the upper boundary of the next higher unit, the Tybo shale, the anticlinal area shows two distinct anticlinal axes which trend northwest. The northern of these axes is just south of the cliff that forms the top of the canyon rim. To the north and northeast the dips are gentle, but on the south and west they are steep and in part overturned. The crest of the southern anticline is just north of the 2 G fault. Here also the overturn is to the south, so that although the Tybo shale is cut by the 2 G fault on the surface south of the Hales shaft, the mine workings directly below to a depth of nearly 900 feet show the stratigraphically higher Hales limestone against the fault.

The area west of the Uncle Sam fault and north of the Dimick fault presents a similar structure. The belt of dark shale within the Pogonip limestone outlines an anticline whose axis trends northwest. On the crest and northern limb the dips are moderate, but on the southern limb, in the portion north of Tybo Canyon, nearly vertical dips prevail. Overturned beds are found south of the canyon, close to the Dimick fault. Similarly the Eureka quartzite has vertical and overturned dips against the Dimick fault on the west end of Air Shaft Ridge, but progressively more moderate northward dips beneath the Lone Mountain dolomite north of the valley.

Outside this narrow belt of sharp folding there are only gentle flexures.

In the triangular area about 3,000 feet long that lies between the 2 G fault and the Uncle Sam fault the beds of Pogonip limestone dip gently to the north and northwest, but farther south, close to the Uncle Sam fault, on the ridge south of Fairbanks Canyon, southerly dips prevail. Eastward, near the Swarbrick prospect, the dips are steeper and dominantly to the northwest. The steeper dips (over 40°) are nearly everywhere close to faults and suggest drag, but the general attitude of the beds as outlined

above suggests that south of the 2 G fault there is but less pronounced anticline.

On the high ridge north of Tybo Canyon the rocks are broken by faults, show prevailing rather gentle dips, becoming less steep to the north. However, close to the area of porphyry that has been mentioned is the Uncle Sam fault, steeper westerly to northwest.

The folding involved the Lone Mountain dolomite. The relation of the Gilmore Gulch formation to the dolomite, it is thought likely that the folding was contemporaneous with the deposition of the Gilmore Gulch formation was deposited, for the flow banding of the dolomite correspond to the flow banding of the younger lavas are likewise tilted to the southwest angle. The only definite evidence as to the date of the folding, therefore, is that it is later than upper Silurian. It is presumably post-Paleozoic and contemporaneous with the revolution that affected the rocks of the Sierra Nevada in the eastern part of the Basin and Range province in late Jurassic time or with that which had its maximum in the Rocky Mountains in early Tertiary time. The folding in the eastern part of the Basin and Range province

FAULTING

GENERAL FEATURES

Several stages of faulting are shown by the relation of the faults to one another and by the relation of the faults to the porphyry, the quartz latite flow, and the later lavas. It is believed that during each of these stages of movement took place along the earlier faults.

It is suggested that the oldest major fault is the 2 G fault, which the present 2 G, Dimick, and Gilmore faults are. It was formed as a result of the folding described above. The oversteepened southwest limb of the southern anticline of origin is indicated by the position of the fault relative to the overturned anticline and by the fact that the movement on this fault is in the reverse direction.

A possible alternative explanation of the 2 G fault is its continuation in the Dimick and Gilmore faults is a transverse fault of similar character to those in the Gold Hill district, Utah. On the assumption that localized pressure was exerted from the east, it

⁴Nolan, T. B., *Geology and ore deposits of the Gold Hill district, New Mexico*. Geol. Survey Prof. Paper (in preparation).

that the fault developed early in the period of regional compression and that the folding, accompanied by minor thrusting (as in the gently dipping fault separating the Swarbrick and Tybo formations on the eastern ridge south of the canyon) was localized to the north of the fault. The relatively unfolded area to the south may either have remained stable or moved westward without folding along an overthrust fault whose plane is below the depth reached by mining developments on the 2 G fault.

Study of an area larger than that included in the present investigation would be necessary to determine which of these hypotheses to adopt, but the northerly dip of the fault and its position on the overturned limb of the fold incline the writer to prefer the first one.

It is possible that two other faults were formed at the same time. The fault along the ridge north of the canyon in the eastern part of the area mapped dips 30° – 45° and does not involve the Tertiary volcanics. The relations shown in section E E', Plate 1, might be interpreted as the result either of normal faulting or of thrusting. The fault that crops out just west of the crest of the eastern ridge south of the canyon (section A A', Plate 1), does not continue south of the 2 G fault nor north of the fault that follows the east slope of the ridge and may be the result of thrusting from the east.

Probably at some time in the early Tertiary—before the beginning of the upper Miocene, if the sediments above the rhyolite are correctly correlated with the Esmeralda formation, and probably before the deposition of the Gilmore Gulch formation—there was widespread normal faulting throughout the region. To this period belong the Uncle Sam and Bunker Hill faults and other minor faults in the western and central parts of the district.

The Uncle Sam fault cuts the earlier 2 G fault, probably with approximately vertical downthrow to the west, so that the western segment of the original fault, the present Dimick fault, which, like the 2 G, dips steeply to the north, crops out south of the intersection of the Uncle Sam and 2 G fault.

There are porphyry dikes along the Uncle Sam, 2 G, Dimick, and Gilmore faults. The Dimick fault, however, cuts the quartz latite flow, and the quartz latite mass west of the Uncle Sam fault is depressed relative to the area on the east. Therefore additional faulting must have taken place after the intrusion of the dikes along the faults and the outflow of the quartz latite, to which they may have been conduits. This faulting must have been earlier than the final period of faulting, for the quartz latite flow and

the overlying Esmeralda (?) formation are tilted northwest to a greater degree than the later lavas.

The final stage of faulting developed new faults along the eastern front of the range and presumably blocked the range in its present form. Lavas similar in composition to those in the higher western part of the range are present along the eastern front.

These eastern faults appear to be a series of small faults rather than a single fault, and although the amount of movement as indicated by the juxtaposition of the Tybo and Cambrian sediments is of the magnitude of several hundred feet, the individual faults cannot be traced for long distances and are lost where they pass into the area covered by weak Cambrian shales.

The eastern faults may have been as late as the late Tertiary and they have determined the present outline of the range. The present relief is probably in part the result of the range being downfaulted and on the whole less resistant to erosion. This zone of faulting, and the worn-back scarp of the range front is very likely a fault-line scarp rather than a fault scarp.

There is evidence of movement later than the Tertiary which is itself later than the quartz latite, along the eastern front of the western part of the area, but it is not certain whether it is correlated with the development of the range-front. Evidence of later movement on the 2 G fault is seen in the presence of post-mineral gouge in the workings of the Tybo mine. The amount of gouge increases to the west, indicating that such late movement as took place along this fault was a sequence of renewed movement on the Uncle Sam fault. Along the Uncle Sam fault there has also been movement of the quartzite porphyry dikes that follow the fault plane. The Tybo formation dips away from the Uncle Sam fault, and the Esmeralda (?) formation dips more gently farther west, and the Esmeralda (?) formation have the same dip as the western part of the Gilmore Gulch formation. Above the Esmeralda (?) sediments, however, dip is not uniform. This fact seems to indicate that the renewal of movement on the Uncle Sam and probably the Dimick fault are two stages, for the presence of an old topography of the range renders it unlikely that the northwestward tilt of the younger lavas is a regional tilt consequent upon the movement on the range front.

The net result of these different periods of faulting was to leave the central part of the district as a horst of older formations bounded on the east and west by relatively depressed younger rocks. On the east the bounding faults were newly developed and dip to the east, with the younger rocks on the hanging-wall side, but on the west the planes of the older faults were followed in the renewed movement, thus bringing the younger rocks in places below the older.

The degree to which movement later than mineralization affected the area west of the Uncle Sam fault naturally has an important bearing on the future mining development in this



Figure 4—South wall of Tybo Canyon showing trace of 2 G fault, east of Hale's shaft.

area, for it may be that along the Dimick fault the zone of productive mineralization has been depressed below that of the Tybo mine on the east. Data are lacking, however, for any estimate of the magnitude of such movement.

INDIVIDUAL FAULTS

2 G fault—The 2 G fault (Figs. 4 and 5 and sections B B', C C', and D D', Plate 1) is a reverse fault formed along the overturned southern limb of the southern of the two anticlines outlined by the Tybo shale. The position of this fault and its displaced segment, the Dimick fault, relative to the overturned

southern limb of this anticline suggests the result of the oversteepening of this fold. The conclusion is that it is a transverse fault along which the strata are largely horizontal—to the west north of the fault—folding and minor thrusting to the north, and slight deformation of the sediments to the south of the westward-moving northern block, which either remained stationary or moved westward.

The fault is certainly traceable for 8,000 feet. The Sam fault eastward to the Swarbrick property of the ridge overlooking Hot Creek Valley. The bodies of the Tybo mine and has been developed from that mine for a horizontal distance of about 1,000 feet of nearly 900 feet below the collar of the 2 G shaft. The strike is about N. 68° W. and the dip is 70° N. The Pogonip limestone, with relatively gentle dip, forms the hanging wall for the entire distance. The northern part consists of Cambrian strata. The limestone forms the hanging wall at the eastern end of the fault. The lower formations, the Tybo and Swarbrick, dip north of the fault cause the Hale fault. The hanging-wall rock of the mine workings, the underlying Tybo formation forms the hanging wall face.

Porphyry is present in places along the fault. The cross cuts in the Tybo mine show that the fault is close to the main fault. The large fault is the intersection of the two branches that diverge from the main fault.

At the western end there are two distinct faults. The Pogonip limestone between them. These branches are on the surface near the 2 G shaft and are close to the Uncle Sam fault. What are the faults have also been developed on the 300-foot level. But the intersection, which pitches to the south, is above the point where the 710-foot level intersects the fault. Another branch from the 2 G fault is developed in the direction from a point about 2,000 feet east of the 2 G and Uncle Sam faults and where it intersects the 2 G fault about 1,000 feet from the 2 G fault.

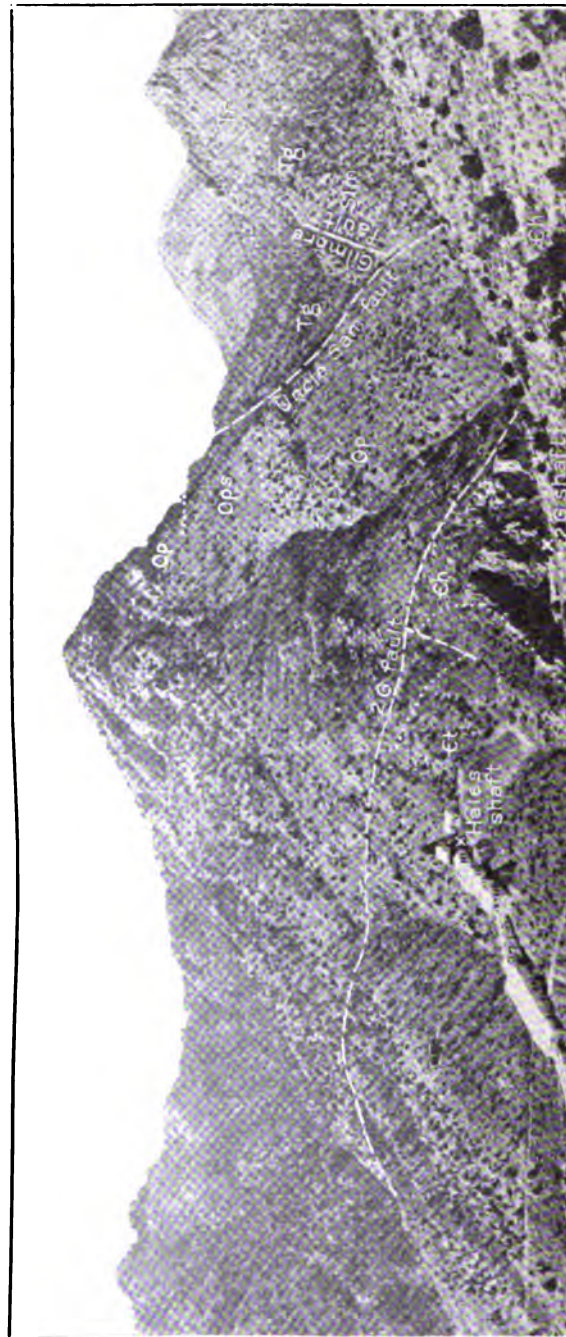
Fossils of lower Pogonip (Beekmantown) are found from the wedge that lies between the main fault and the branch that diverges to the southeast; the presence of the

icates that the displacement is divided between these two branches, with the greater amount on the northern branch.

As no complete stratigraphic section could be worked out in the district the apparent vertical displacement on this fault is not measurable, but it may exceed 6,000 feet. On the north side the lowest stratigraphic unit in contact with the fault, the Swarwick formation, which has a thickness of at least 2,000 feet above the lowest point at the fault contact, is succeeded by 1,600 feet of the Tybo shale and this by at least 1,300 feet of the Hales limestone. To the south fossils identified by Kirk as belonging to the upper (Chazyan) part of the Pogonip were collected close to the fault, and in all considerably more than 1,000 feet of the upper and lower parts of the Pogonip must be present on the south side.

Dimick and Gilmore faults—The Dimick and Gilmore faults (section B B', Plate 1) are regarded by the writer as the continuation of the two western branches of the 2 G fault displaced by the Uncle Sam fault. Their intersections with the Uncle Sam fault are south of those of the two western branches of the 2 G fault with the Uncle Sam fault, and they are much farther apart than the two branches of the 2 G fault. This would be the expected situation of two faults with northerly converging dips displaced approximately vertically by a fault nearly at right angles to their strikes.

The Dimick fault for about 2,000 feet westward from the Uncle Sam fault strikes about west and dips steeply to the north, probably about 80° . Along this portion it has Pogonip limestone, which dips moderately toward the southwest, on the north, and massive dolomite, presumably of Silurian age, whose attitude could not be determined, on the south. Porphyry is present in places along the fault plane. Beyond this point, which probably about coincides with the junction of the Dimick and Gilmore faults, the strike is about N. 60° W. and the dips average 55° to 70° NE. Across the western end of Air Shaft Ridge the Eureka quartzite and for a short distance Silurian (Lone Mountain) dolomite, both with overturned steep northeasterly dips, occur on the hanging-wall side against quartz latite on the footwall. It is probable that there is a branch fault on Air Shaft Ridge north of the Eureka quartzite, for the apparent thickness of the upper part of the Pogonip, as measured from the band of impure quartzite that extends from the central part of the ridge northward to the Bunker Hill fault, is less than 1,000 feet, as contrasted with about 1,900 feet on the north side of the valley. The Dimick fault can be followed for about 1,000 feet north of the



ley until it is lost under the wash. In this section it truncates the strike of the upper part of the Pogonip limestone, the Eureka quartzite, and the lower part of the Lone Mountain dolomite on the hanging-wall side. Quartz latite continues along the footwall. At the northern border of the area covered by the geologic map a fault contact between quartz latite and Silurian (Lone Mountain) dolomite shows parallel strike and dip. If this is the same fault as the Dimick it must have been displaced to the north-east by another fault, for the projection of its strike to the south-east brings it against the Silurian dolomite.

The Gilmore fault can be followed with certainty westward from the Uncle Sam fault for a distance of about 2,000 feet. Further west surface exposures are obscure, but it probably joins the Dimick fault near the west end of Air Shaft Ridge. As the fault crosses the steep hill west of the Uncle Sam fault the trace on the surface is curved, but the strike is about west and the dip averages about 65° N. On the hanging-wall side occurs massive Silurian dolomite, and on the footwall are the sandstone and shale of the Gilmore Gulch formation, showing steep dips close to the fault plane but gentle southwesterly dips a short distance away. The combined displacement on the Dimick and Gilmore faults cannot be even as roughly estimated as that on the 2 G fault, because the total thickness of the Gilmore Gulch and Lone Mountain formations is unknown, and there is no clue to the thickness of strata that may intervene between the Lone Mountain dolomite and the Gilmore Gulch formation. In view of the distinctly different ages of the formations involved it is a reasonable assumption that the displacement of the two faults is of the same order of magnitude as that of the 2 G fault. It is certain that the apparent throw on the Dimick fault alone, where the Lone Mountain dolomite is in contact with the Pogonip limestone, presents a stratigraphic displacement of at least 2,000 feet. To this amount must be added whatever displacement may be indicated by the juxtaposition of the Gilmore Gulch and Lone Mountain formations along the Gilmore fault.

Uncle Sam fault—The Uncle Sam fault (Fig. 5 and sections A A', B B', and C C', Plate 1) crosses the entire district, and as far as could be seen from the ridges on the north and south continues in both directions for a considerable distance. South of the Gilmore fault the upper part of the Pogonip limestone on the east is in contact with the Gilmore Gulch formation on the west. Between the Gilmore and Dimick faults the Lone Mountain dolomite is in fault contact with the Pogonip limestone.

North of the Dimick and 2 G faults Cambrian on the west and the upper part of the Pogonip east. The strike is north from a point a mile the southern border of the mapped area to Tybo north side of the canyon it is about N. 30° W. tions on the hill south of Tybo Canyon indicate of 75° to nearly vertical. What is apparently the 300-foot level of the Tybo mine dips 80° W. of the outcrop relative to the fault on this level a steep westerly dip. If the assumption is correct near the west end of the 710-foot level is also there must be a reversal in the direction of the levels, for the dip in that place is 85° NE. and the fault about 100 feet to the northeast of its position foot level.

If, as seems likely, the regional northwesterly 15° , shown by the lavas younger than the Esmontion, is a result of tilting of the whole area consequent on late faulting along the range front, the original Uncle Sam fault may have been steep to the west. The fault is therefore regarded as a normal fault later fault, which it displaces.

The displacement is large, but the lack of a graphic section prevents accurate measurement of the order of magnitude of 2,000 feet.

Porphyry has been intruded in places along the southern segment the dikes are narrow, but with a maximum width of 1,000 feet, are present in the northern segment.

A branch of the Uncle Sam fault extends north nearly parallel strike across the east end of the Tybo. Limestone regarded as belonging to the Esmontion borders the fault on both sides, but on the west contains narrow bands of impure quartzite or bed repeated by minor faults. As the Hales and Esmontions are lithologically similar, it is possible that the limestone belongs to the Pogonip limestone. No fossils were found in the segment between the two faults.

A peculiar feature of the Uncle Sam fault is the presence of two narrow slivers of quartzite, each less than 100 feet in the plane of the fault, one south and one north of the fault. (See map and section C C', Plate 1.) The quartzite is the same dense white variety as the Eureka quartzite.

mapped as Eureka, but on lithologic evidence alone. The northern mass, which forms a narrow wedge between the upper part of the Pogonip limestone and the Gilmore Gulch formation, may be interpreted as the result of distribution of displacement between two branches of the fault, for its position implies a drop of 500 or 700 feet below the projected position of the Eureka quartzite in the area east of the fault, and it is at a considerable unknown distance above the horizon at which the quartzite would be present in the area west of the fault. The northern part of quartzite, however, lies stratigraphically below the projected position of the Eureka quartzite on both sides of the fault—several hundred feet below west of the fault and much farther below east of it. Therefore, if it is indeed the Eureka quartzite it must be a keystone-like wedge dropped down to a greater extent than the amount of displacement on the fault.

An alternative explanation for the northern mass is that it represents not the Eureka quartzite but a quartzite bed within the Pogonip limestone which, because of secondary silicification along the fault plane, now closely resembles the Eureka. Against this explanation are the facts that silicification was nowhere observed along other fault planes and that the other outcrops of quartzite within the Pogonip limestone do not bear any resemblance to the Eureka quartzite.

Bunker Hill fault—The Bunker Hill fault has a northwesterly trend and diverges from the Uncle Sam fault at a point near the Bunker Hill shaft. It is a normal fault with relatively small vertical displacement, which, as measured by the offset of the top of the Pogonip limestone, is not over 300 feet.

Range-front faults—Insufficient time was devoted to the east side of the range to work out the structure in detail, and along the piedmont that borders the range the exposures are not as good as elsewhere in the district. Along certain of the faults there has been comparatively recent movement, because rocks as young as the quartz latite, Esmeralda (?) formation, and andesite of the western part of the district are faulted down along the east front. Two of them, however, which do not involve the younger rocks, may be older and may have formed during the period of folding and compression.

A fault with comparatively low dip to the northeast—from about 30° to not over 45°—crops out just west of the crest of the ridge that borders the district north of the canyon. On the

hanging-wall side is the upper part of the Pog only a few feet intervening between the f Eureka quartzite, which caps the hill. As are here folded, the structural relations (sec are explainable either on the assumption of thrust, which has moved the crest of another

A similar fault, for which the evidence stronger, lies west of the crest of the easter canyon. Slate of the Tybo formation lies to stone that is assumed to belong to the Hale no fossils were found, to the east. The fa parallel to the strike of the beds on both si tion was due to the thinning of the outcrop the south and to minor discordance in struc along its course. The dip is unknown, but crop suggests that it is fairly gentle to the cut off on the north by the fault that follow the ridge. On the south it is traceable as f pyhry along the 2 G fault. It does not cut 2 G fault, but on the other hand no corro observed south of the 2 G fault to the west. tions (section A A', Plate 1) can be explai either a normal or a thrust fault, as it cuts cline obliquely. If it is a normal fault it than the porphyry. It does not cross the assumption therefore requires that the hanging-wall block must have been accomp on that part of the 2 G fault east of the int thrust fault it is best explained by supposin is a transverse fault, along which the north west, and that this fault developed as a min tion with this westward movement.

Near the extreme southeast corner of the geologic map is a small outcrop of limestone brian fossils were obtained. This limestone below the shale of the Tybo formation, but mined whether this relation was due to an thrust fault, or whether the limestone might Tybo formation not found elsewhere in the

The other faults along the eastern border to be comparatively young normal faults, the Esmeralda (?) formation and younger l has been intruded along them. These faults

th and northwest, and the dips in the few localities where they could be determined showed a range of from 35° to 70° E. None of the faults could be traced far, and all were lost northward in the shale of the Tybo formation, possibly dying out as flexures, although the magnitude of the displacement at their south ends, as shown by the downfaulting of the Tertiary lavas, makes this explanation doubtful.

The best-exposed fault of this group follows the eastern base of the ridge south of the mouth of the canyon. Along most of its course it separates the Cambrian Hales and Tybo formations. South of the point where it cuts off the 2 G fault Pogonip limestone lies on the footwall side, and still farther south dacite, similar to that which occurs above the Esmeralda (?) formation in the western part of the district, comes in on the footwall side along an eastward-trending fault.

This east-west fault, which dips steeply to the north, possibly marks the position of the 2 G fault as displaced by the fault just described. If so, it is to be supposed that the fault was at one time covered by the later flows and that when the faulting along the range front took place the old fault broke through this cover, and the block of andesite now exposed is the result of gravitative downfaulting along these two faults, normal with respect to the north-south fault but reverse to the steep dip of the rejuvenated east-west fault. The other faults that lie to the east seem to form a definite zone rather than a single fault and appear to be in échelon arrangement. The outcrops, however, are poor in this part of the area, and the distance from definite fixed points has rendered their exact position uncertain. In the few localities where the actual fault plane is exposed there is abundant gypsum and large crystals in the fault gouge. This mineral was not seen in connection with any of the western faults.

The position of the quartz latite relative to the dacite and andesite in the extreme southwest corner of the area mapped suggests crust faulting along the range front, but the field relations are obscure. It appears from the contact of the quartz latite and dacite to the west of the fault that the surface of the quartz latite was irregular. Therefore, if there is some horizontal component the major direction of faulting may be normal. The dacite, as shown by the dip of the interbedded tuff, is strongly folded, and other faults may be present. Certainly the relation of the quartz latite to the older rocks to the north indicates normal faulting.

GEOMORPHOLOGY

No geomorphic study of this portion of the range was made, and the following notes are consequently more tentative than if the conclusions had been checked by observation over a wider area.

The high ridges north of Tybo Canyon show older topography at altitudes slightly greater than the present. The contrast is abrupt between the rolling upland surface and the steep, vertical walls of the present canyon. The southern ridge, rising nearly to the same altitude and showing a distinct line, is narrower and no longer preserves the original topography. This mature surface is also preserved on the crest of the range. A little waterworn gravel is found on the divide west of Tybo, at the point where the railroad power line crosses the range, at the height of about 10,000 feet.

The western slope of the range coincides with the rhyolite flows, but as this old topographic surface is older than the rhyolite as well as the older rocks, this is directly the result of the tilting of the range by faulting toward the east, but must be a dip slope of erosion of less resistant overlying material. For no major movement can have taken place on the Tybo or other faults in the central part of the district since the formation of this surface.

Similar old topographic surfaces are found on the Toiyabe Range, Nevada and probably represent remnants of a Pleistocene or late Pliocene surface of low relief. On the Toiyabe Range, about 30 miles to the northwest, this surface is preserved at a general altitude of about 10,000 feet. This surface was broken up by renewed faulting during the Pliocene epoch, but it is uncertain whether the ranges and basins from this recent faulting were formed as independent blocks in an area of low relief, or whether, as is usually assumed, there was first a regional uplift followed by faulting, which outlined the present valleys. The presence of postmature surfaces on nearly all the basin ranges at different altitudes is suggestive of the first hypothesis; on the other hand the old surface is not a peneplain, and the original differences in altitude are possible, and in some cases one of interior drainage the old topography may be dependent on base-levels at different altitudes.

Blackwelder⁵ has emphasized the difference between

⁵Blackwelder, Elliot, Jour. Geology, vol. 36, pp. 289-311, 1928.

The Great Basin which follow faultline scarps and those which are a relief that is directly due to faulting and which are bordered by fault scarps, more or less worn back according to the distance of the rock and the interval since the activity of the fault. It seems probable that the eastern front of the Hot Creek range is a faultline scarp rather than a primary fault scarp and that the present relief of the range is due to erosion of material at the foot of the range-front faults rather than directly to faulting.

As far as can be seen from the road along the valley the range is bordered by Tertiary lavas for some distance south of the Tybo District. Spurr⁶ crossed the range at Hot Creek, about 10 miles south of Tybo, and his section shows lavas along the eastern front at that point. Between Tybo Canyon and Hot Creek, however, Cretaceous rocks form the range front. These rocks, as shown by exposures in the pediment south of the canyon, are faulted and are in fault contact with the Tertiary formations.

The Esmeralda (?) formation, overlying the quartz latite, and the quartz latite itself, where weathered and fissured, are more susceptible to erosion than the later lavas. Where the Esmeralda (?) formation, of which traces yet remain in the pediment along the range front, was originally present in considerable thickness, as at the mouth of Tybo Canyon, the Tertiary formations east of the present range may have been removed by erosion, giving the present faultline scarp. Farther south, where the more durable later lavas rested directly on the rhyolite, these lavas form the front of the range, possibly bounded by other faults.

There were two distinct stages in the sculpture of the range. At the close of the first stage a rather wide valley was formed between the present Tybo Canyon; later erosion carried away the valley fill, deposited during the earlier stage, thus revealing the pediment that fronts the range, and cut the canyon to a greater depth. Remnants of the older valley remain in gravel-covered spurs at heights of several hundred feet above the present canyon floor. The wide bench of altered quartz latite southwest of the Dimick fault was probably developed in this stage, aided by the stripping of its cover of weak tuffaceous sediments of the Esmeralda (?) formation. A remnant of the valley fill of the early stage is preserved in the huge gravel ridges that project into the valley a short distance north of the mouth of the canyon. (Figure 6.)

Spurr, J. E., *Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California*: U. S. Geol. Survey Bull. 208, pp. 87-88, 1903.

The cause of this lowering of base-level was not clear at first, but on looking southeast from the hills from the Tybo district a marked gap appears in the hills at the south end of the Hot Creek Valley. Perhaps there has been a capture of the Hot Creek Valley by Reveille Valley, which lowered the base-level and laid bare the pediment of Tertiary rocks that had been buried east of the Tybo district.

HISTORY AND PRODUCTION OF THE DISTRICT

The Tybo district is one of the older districts in Nevada. Like others of its type, it was first worked for its



Figure 6—Gravel ridge in Hot Creek Valley, north of Tybo district.

were rich in silver. It owes its recent reopening to the selection flotation process, which has permitted the mining of the mixed lead and zinc ores found at the district.

The principal and only productive mine is the Hot Creek mine, which at the time of the writer's visit was producing 100 tons of ore. The plane of the 2 G fault. The Swarbrick mine is developing ore along the 2 G fault. Other mines have had some production in the past are the Gilmore mine and the Bunker Hill mine, which probably obtained their names from the faults which derive their names from the Bunker Hill mine, which probably obtained its name from the Bunker Hill mine.

¹Data largely from Blackburn, W. H., Milling methods for the zinc concentrator of the Treadwell-Yukon Co., Ltd., at Tybo, Nevada, Bur. Mines Information Circ. 6430, March, 1931; and John B. Farish, dated October, 1910, inspected through Treadwell-Yukon Co.

ore along either the Bunker Hill fault or the Uncle Sam fault. Other prospects are being developed along smaller fissures apparently unconnected with the major faulting.

The earliest discovery of ore was made in the Tybo district in 1879. Small seams carrying rich oxidized silver ore were worked first. The 2 G lode was discovered in 1871, and the Tybo Consolidated Mining Co. erected a smelter in 1872. Charcoal burned in the local pinon timber was used as fuel. Work in the mine was extended as far as the present 400-foot level, but the primary white ore could not be treated. The company failed in 1879, and the property was sold to defray its debt. During the period from 1872 to 1879 a total of 61,439 tons of ore from the Tybo mine and 156 tons from other properties were smelted, yielding 100 tons of lead bullion, which contained 1,743,000 ounces of silver and 15,330 ounces of gold, equivalent to a recovery of 11 per cent of lead and 27.5 ounces of silver and 0.24 ounce of gold to the ton of ore.

Mining continued intermittently under different owners until 1908. A 20-stamp mill was in operation, and the silver content of the remaining oxidized ores was recovered by the Reese process—pan amalgamation followed by chloridizing roast. About 80 per cent of the silver content of the ore is reported to have been recovered. The production for this period, apparently from the Tybo mine, is said to have been 834,000 ounces of silver and 5,030 ounces of gold from 42,000 tons of ore.

Unsuccessful attempts to reopen the mine were made in 1901, 1906, and 1917. The attempt in 1917 was on the largest scale. The Louisiana Consolidated Mining Co. acquired the principal properties of the district and erected a flotation concentrator and a smelter, but as no method was available at that time for the separation of the galena and sphalerite, the venture was unsuccessful, and the plant was closed in 1920. The properties included the entire western part of the district and along the 2 G fault as far as the point where it crosses the ridge south of Tybo Canyon, as well as some ground along the eastern front of the range, were acquired in 1925 by the Treadwell-Yukon Mining Co. After extensive exploration, the construction of the present concentrator was begun in November 1928, and the mine made its first production in May 1929. The production for a typical month (March 1930), as given by Blackburn, is 703.5 tons of lead concentrates, containing 59.90 per cent of lead, 4.00 per cent of zinc, and 87.10 ounces of silver to the ton, and 625 tons of zinc concentrates, containing 2.55 per cent of lead, 47.60 per cent of zinc,

and 14.28 ounces of silver to the ton, from 9, a tenor of 5.95 per cent of lead, 4.14 per cent of silver to the ton. The concentrates to Tonopah, a distance of 70 miles, and then the lead concentrates to Selby, Calif., and the Kellogg, Idaho. In the summer of 1930, owing to zinc, the zinc concentrates were being shipped alone were being shipped.

ORE DEPOSITS

GENERAL FEATURES

The ore mined in the district at the present is a stanniferous lead-zinc sulphide ore. There are also some veins that contain argentiferous manganese ore, but as yet these have never proved productive. The only mine in operation was the Tybo mine, owned by the Yukon Co., Ltd., and therefore the data on the district could be procured are derived largely from the Tybo mine. All the ore so far mined from the district has been from the bodies along the 2 G fault. This fault has a length of about 2,500 feet at its west end by the 300 level, and for over 300 feet in its eastern part by the 710 level. The brick prospect, and mineralization is evident in the intervening portion, though as yet no ore has been developed there. The Gilmore, Dimick, Bunker Hill, and others are also known to be mineralized, though no ore has yet been developed on these faults.

Porphyry dikes tend to follow all the faults in the district, the range front, and to a large extent the ore bodies. Most of the ore minerals of the Tybo mine are of the porphyry rather than the limestone, and the veins of the mine coincide with large masses of porphyry along the fault.

Mineralization along the fault was not continuous for considerable distances the drifts following the fault are only a gouge-filled fissure. Elsewhere there are streaks to several inches of barren gangue material, however, that nearly 50 per cent of the ore is developed portion of the 2 G fault in the Tybo mine. The 300 level has either been stoped or shows the ore minerals. The largest body, on the 710 level, is in the shaft, has a drift length of over 300 feet and a width of about 50 feet.

MINERALOGY

The primary sulphide minerals are pyrite, sphalerite, galena, alcopyrite, pyrrhotite, and arsenopyrite. Under present conditions only the galena and sphalerite are ore minerals. The best ore consists of mixtures of these two in varying proportions, in places irregularly segregated, elsewhere intimately mixed. In nearly all the ore, however, varying amounts of the other sulphide minerals are present, pyrite predominating, and the gradation between ore and material containing abundant sulphides but too low grade for mining is commonly due to increase in the amount of pyrite present. Of the two ore minerals galena is slightly the more abundant; an analysis of a composite sample of the ores between the 710 and 400 levels gave 7.38 per cent of lead and 5.55 per cent of zinc, and the yield from a typical month's mill run was 703.5 tons of lead concentrates and 625.0 tons of zinc concentrates from 9,930 tons of ore treated. The galena is the only mineral that contains noteworthy amounts of silver. Assays of pure material gave a content of 110 to 130 ounces of silver to the ton, as against a maximum of 20 ounces to the ton for sphalerite and 11 ounces for the pyrite (including pyrrhotite and marcasite). In the mill run referred to above, of a total saving in silver of 74.9 per cent of the assay content of the ore, 65.4 per cent was in the lead concentrates and only 9.5 per cent in the zinc concentrates.

The sphalerite is dark brown to nearly black. Analyses of specimens show 10 to 15 per cent of iron, but as polished sections studied by M. N. Short, of the United States Geological Survey, included specks of chalcopyrite and arsenopyrite, a part of the iron may be due to these inclusions. The sphalerite is more coarsely crystalline than the galena and, though for the most part intimately mixed with the galena, occurs also in nearly pure coarsely crystalline masses several feet in diameter.

Pyrite is the most abundant of the sulphide minerals. In places the vein consists entirely of this mineral with only a little gangue. None of the ore is completely free from it. A part of the pyrite is massive, and a part is rather coarsely crystalline. The porphyry nearly everywhere throughout the district is impregnated with pyrite to a greater or less extent. Also, though rarely, pyritic seams are present in the limestone. In places, where the ore minerals have replaced limestone instead of porphyry, pyrite occurs in poorly defined layers as much as one centimeter in thickness, separated by similar layers containing galena, sphalerite, and gangue. This occurrence is rather rare and may

represent the preservation of the original bedded limestone, but may possibly be due to rhythmic bedding. Commonly, however, the rock, whether limestone or dolomite, has been so crushed and sheared along the fault that its original structure was entirely controlled by this later crushing.

The writer gained the impression, though not confirmed by any quantitative observations, that there is a marked increase of the pyrite with depth—that is, the deeper the vein in which the principal sulphide mineral is found, the greater proportion of the drifts in the lower levels. At least this increase in pyrite is at the expense of the veins that carry calcite with disseminated pyrite at the upper levels rather than a substitution of the ore-bearing material. In general the ore bodies tend to be bordered, particularly at the strike ends, by masses of pyritic material, and the pyritic “tails” to the ore bodies consisting of thin layers of several inches in width with sparsely disseminated pyrite.

Owing to the high freight cost the pyrite, and consequently a little silver, is not saved.

Arsenopyrite is widespread but nowhere very abundant. The total arsenic content of a composite sample of the ore is 0.59 per cent. It is present to some extent in all parts of the ore bodies, but is most readily recognizable in the porphyry. Small crystals may be seen scattered through the altered porphyry for distances of several feet from the more massive sulphides.

Chalcopyrite is inconspicuous and is closely associated with sphalerite. The analyses cited above showed only 0.02 per cent.

Pyrrhotite is sporadic in its occurrence, and its abundance is uncertain. It was recognized in several places where it was collected and occurs in all parts of the mine. Its proportion, probably less than 1 per cent, of the ore is small. Concentrates proved to be magnetic, so it is not particularly unimportant.

The ore bodies themselves consist largely of siliceous material and only subordinate nonmetallic minerals. Fine-grained quartz is present but is usually inconspicuous in the ore. The amount shown in an analysis of the ore is 32.05 per cent. This includes not only the silica present as quartz, but also the amount present in the sericite and other silicates.

pyrite that adjoins the ore. The quartz, however, is so inconspicuous and finely divided through the sulphides of the ore that its relative abundance may be underestimated.

Coarsely crystalline white calcite is a prominent gangue mineral. In places it occurs as blotches or streaks within or adjoining the ore, but it is more abundant outside the ore bodies in the barren portions of the veins. In places the veins consist of several feet of coarsely crystalline white calcite. The Dimick vein, at the west end of Air Shaft Ridge, just south of the road, has a thickness of about 15 feet of calcite without apparent admixture of ore minerals. A similar calcite vein branches off from the Gilman vein a short distance west of the Uncle Sam fault.

Several small veins carry considerable manganese oxide associated with quartz and coarsely crystalline dark manganiferous calcite. At the Larsh prospect, on the north side of the gulch about a mile east of Tybo, such material is said to have a high content of silver.

Study by M. N. Short of polished sections of the ore minerals indicates that on the whole the pyrite and arsenopyrite are probably earlier than the sphalerite and galena. The pyrrhotite seems to be contemporaneous with the galena and definitely earlier than the pyrite and arsenopyrite. The coarse-grained calcite seems to be distinctly later than the ore minerals; on the other hand, as pyrite is in places contemporaneous with the calcite, perhaps even later. Pyrite is probably of more than one generation or was deposited continuously throughout the period of mineralization.

Probably the manganiferous calcite, which on weathering gives color to the veins rich in manganese oxide, may represent a later stage in mineralization.

OXIDATION AND ENRICHMENT

Oxidized minerals have been almost entirely mined out, and those remaining are no longer worth mining. Evidence of oxidation, chiefly in the form of limonite and limonitic pyrite, is seen as deep as the 710 level of the Tybo mine, but in the Warbrick prospect, on the east front of the range, which is at a higher absolute altitude and is considerably higher above the Tybo level as controlled by the main valley, sulphides are present with only minor oxidation. Oxidation seems to have extended to the greatest depths in the Tybo mine at the west end, close to

the Uncle Sam fault, probably because there was a general disturbance along the 2 G fault in this part coincident with readjustment along the Uncle Sam fault.

The oxidized ores mined from the 300 level to the surface are high in silver, and some supergene sulphide enrichment of metal is indicated by the fact that both pyrite and sphalerite in the upper levels have a relatively high content of silver. Sphalerite from 12 to 20 ounces to the ton in the upper levels of the mine as against 7 to 10 ounces to the ton in the lower levels and that of pyrite from 8 to 11 ounces to the ton in the upper levels as against 3 to 6 ounces to the ton in the lower levels. A supergene silver mineral was identified in the upper levels. Specimens from the 300 level, however, show evidence of later pyrite, presumably of supergene origin, and some sulphides. Mr. Short, moreover, identified marcasite as a replacement product of pyrrhotite in ore from the 300 level. It therefore seems likely that supergene pyrite and sphalerite carry sufficient silver to account for the higher silver content of the pyritic minerals of the upper levels.

ROCK ALTERATION

Rock alteration along the vein is largely confined to the porphyry. In places dolomite was observed in the upper levels. Dolomitization was sporadic and seems to have been not more prevalent along faults that show no apparent alteration. In places the limestone adjoining the ore was altered to a slight extent. In the porphyry, however, alteration is widespread. Close to the ore the porphyry is so altered that quartz phenocrysts are the sole remnants of the original minerals. Sericite and calcite are the principal minerals in the porphyry. Sericite is widespread and is present to a more or less extent in all the specimens from which thin sections were cut. Calcite is more abundant close to the mine. Specimens taken near the ore show that the porphyry is altered to an intimate mixture of calcite and sericite, but the quartz phenocrysts remain as residuals of the original rock, but in a few of the specimens examined even the sericite is replaced by calcite and sericite.

Chlorite is present in places in the altered porphyry along the fault. It replaces biotite, but is itself largely replaced by calcite and sericite.

ORIGIN

The ore deposition is clearly related to the intrusion of the Tybo dike which for the most part followed preexisting faults. It is correctly assumed that the rock of the porphyry dike is of the same age as the ore.

that of the great quartz latite flow west of the Uncle Sam fault and that these dikes were in part, at least, feeders to the flow, it follows that there must have been an interval between the intrusion and effusion of the quartz latite and the introduction of the ore. During this interval movement took place along several of the faults—certainly the 2 G, the Uncle Sam, and the Dimick. The Dimick fault gives the clearest evidence of this movement, for mineralization, though mostly of the unproductive type characterized by the coarse calcite is present where the older rocks are in fault contact with quartz latite flow. There is a suggestion that the mineralization was a pulsatory process, beginning with chloritization of the biotite phenocrysts in the porphyry and deposition of pyrite and arsenopyrite. This was followed by the main period of ore deposition with sericitization of the porphyry and replacement by the ore minerals and pyrrhotite, probably also with deposition of pyrite, and finally by barren calcite with some pyrite. As some movement on the fault intervened between the intrusion of the porphyry and ore deposition, it is inferred that where the small dikes were present along the faults they were extensively fractured and afforded better channels for ore-bearing solutions than where both walls were limestone and the new movement was simply a continuation of the old without development of new fissures. This affords a possible explanation of the greater preference of the ore for the porphyry, because, if physical conditions were the same, it would be expected that the more readily soluble limestone would have been more extensively replaced. As the dike that has been replaced by the ore has been intruded along a fault, it is possible that the age of premineral age has been effective in preventing the penetration of the limestone by ore-bearing solutions.

Another possible factor which may have in part controlled the deposition of the ore along fractures rather than replacing the limestone is the probable shallow depth at which mineralization occurred. If the ore deposition along the 2 G fault followed the intrusion of the porphyry dikes and if these were contemporaneous with the extrusion of the great quartz latite flow, the total thickness of cover could not have been more than a few hundred feet, and it is therefore possible that, owing to relatively quick cooling, the time during which the ore-depositing solutions were active was relatively short. Consequently the time may have been inadequate for the solution and replacement of the unfractured limestone, and if so, mineralization was confined to the intensely fractured portions of the lode, principally the porphyry veins along the fault, where circulation was comparatively free.

The fact that porphyry intrudes what appears along the fault is indicative of near-surface solutions, penetrated the zone of active ground.

Ore deposits of this general type of mineralization throughout the Rocky Mountain province and associated with the upper portions of intrusive rocks. In Nevada deposits of this type tend to be more common in the eastern part of the State. On the basis of their similarity to those of the Rocky Mountain region, it has been assumed they are of early Tertiary age.⁹ The Tybo ore deposits, similar in general mineral content, may have been deposited nearer the surface than the Rocky Mountain type, in general, for it is associated with rocks that are at shallow depth. The uncertainty as to the age of the Gulch formation also makes doubtful any age assigned to this formation, as was first supposed, is of Cretaceous age. It may well be that the ore deposits are, as would be expected from their mineralogy, contemporary with the basic rocks of the Rocky Mountain region, and that erosion has since covered the monzonitic stock from which the rhyolite flows shoot. This leads to the inference that the ore deposits possibly apophyses from larger limestone reefs at depth. On the other hand, the Gilmore Gulch formation has a certain resemblance to the Tonopah formation. Its tuffaceous nature, the apparent presence of a flow of silicic lava, and the conformity in dipping with the base of the quartz latite flow suggest that the formation is of later Tertiary age, of Oligocene or Miocene but probably younger than the Eocene. It is then, though differing in character, might be contemporaneous with that of Tonopah.

At Tonopah¹¹ silver ores associated with the quartzite give place in depth to base-metal sulphide ores. At Tybo manganiferous silver ores, such as in the Larsh prospect, may represent the roots of the bearing zone, now eroded, and it is possible that the silver of the oxidized ores of the Tybo mine

⁹Butler, B. S., Ore deposits of Utah: U. S. Geol. Surv. Bull., pp. 195-201, 1920.

¹⁰Ferguson, H. G., Nevada mining districts: Econ. Geol., vol. 131, 1929.

¹¹Nolan, T. B., The underground geology of the western mining district, Nevada: Nevada Univ. Bull., vol. 24, No. 1, 1929.

¹²Nolan, T. B., loc. cit., p. 34.

due to concentration of the silver content from primary ore is usually richer in silver than that now being mined at greater

correct interpretation of the problem outlined in the pre-paragraphs has a possible bearing on the future prospects of the district. If the deposits as now mined represent the upper part of a lead-zinc deposit of the Rocky Mountain type in which the ore has not yet reached a sufficient depth to reveal the type of intrusive rock usually associated with such a deposit, it may be possible that at greater depth lateral replacements along the bedding planes of the limestone will be encountered, which may contain large and cheaply mined ore bodies. The history of mining at Pioche,¹² where the early work was confined to a veinlike deposit along a dike and later work has developed large replacement bodies in the Pogonip limestone, gives hope for such a discovery. On the other hand, if the ore deposition belongs to a later period and the associations are entirely with near-surface rocks without close connection with deep-seated intrusive rocks, it is less likely that a change in habit of the ore bodies will be encountered in depth, but with greater depth the ore may become increasingly pyritic until the limit of profitable extraction is reached. Certain similarities with the geology of the Tonopah—the resemblance of the Gilmore Gulch and Tonopah formations, and certain features of the mineralogy—suggest that this is perhaps the more likely hypothesis; but the evidence is not all strong.

However, there is reason to expect a considerable production of ore if prices are normal, even if ore does not continue to great depths. The ore body exposed on the 710 level is one of the largest and richest in the mine, and since the writer's visit the same body has been cut on the 860 level. Therefore, there is an abundance of considerable undiscovered ore on unexplored portions of the 2 G fault at and above this level. The position of the eastern ore body relative to the surface geology indicates that development east of the shaft is approaching a large mass of porphyry at the intersection of two branches of the 2 G fault. Therefore, the prospects would seem good for a considerable extension of ore-bearing ground eastward along the fault.

The other principal faults along which there have been intrusions of porphyry are the Gilmore, Dimick, and Uncle Sam. All these faults have been prospected to some extent and have yielded

estgate, L. G., and Knopf, Adolph, Geology and ore deposits of the Pioche district, Nevada: U. S. Geol. Survey Prof. Paper 171, p. 53, 1932.

small quantities of ore. There was, however, payment along the Uncle Sam fault, and it is therefore along these faults the ore-bearing zone has been developed by this faulting and will be found at greater average depths than now being developed along the 2 G fault.

The dikes and sills of porphyry not associated with the faults will probably not in general repay prospecting. They are also somewhat sericitized, as a shattering of the rock seems to have been a necessary preliminary to ore deposition; this is confined to the major faults. Galena has been developed, however, as at the Bresnahan and Ker prospects, notwithstanding any major fault.

MINES AND PROSPECTS

TYBO MINE

The Tybo mine of the Treadwell-Yukon Co., is the largest mine in the district which has been extensively worked. The data on mineralization (pp. 44-48) are largely based on observations in this mine. The following notes are confined to a summary of the development at the mine as of August 1930. The history of mining operations is given on pages 42-44.

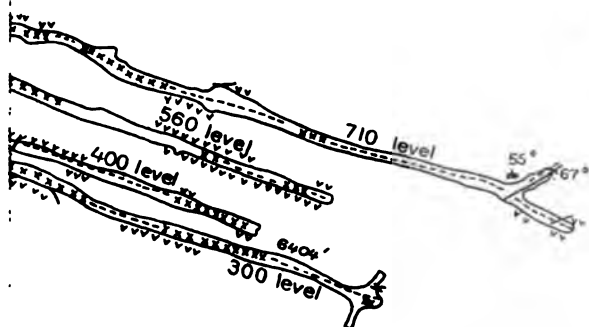
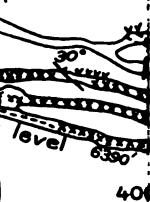
The mine (Plate 2) is developed from two shafts, the Hales and 2 G shaft. The 2 G shaft was the work of the old company, deepened during recent operations. The Crosby shaft was sunk by the present company and is now the main shaft. The Crosby shaft, at the west end of the mine, connects only with the now inaccessible 200-foot level.

Former operations consisted of shallow surface workings at levels at 100-foot intervals below the collar of the shaft. The outcrop of the western portion of the vein, which is lost under the wash west of the 2 G shaft, at a distance of over 1,000 feet eastward, is marked by a series of narrow stopes (Fig. 7), and some stoping has been done by a tunnel and shaft in the gulch, east of the Hales shaft, in the flat between the 2 G shaft and the Uncle Sam fault. These contain shallow stopes, giving a total distance of about 1,000 feet from which oxidized ore was obtained near the surface. These old workings and the 100- and 200-foot levels are now inaccessible. The ore above the 300 level was in large part developed by the former owners, but this level has been developed by the present company, and much additional ore has been obtained. The 400 level, though started by the former owners,

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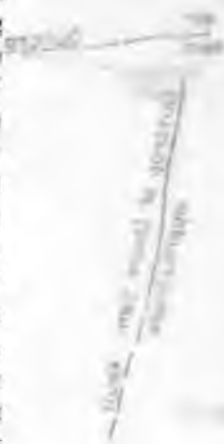
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the work of the present company. The lower levels—the 560-, 660-, and 860-foot levels—have been run in the last few years. Of these the 710-foot level is the most extensive. The 860-foot level, which at the time of visit had cut the vein east and west of the Hales shaft but on which no drifting had been done, has not been extended to develop ore beneath the large body east of the shaft on the 710-foot level.

The mine is entered by an adit from the north which connects



Figure 7—Old stopes on 2 G fault.

the Hales shaft, but ore is hoisted to the top of the shaft and goes thence to the mill on the hillside below the shaft. The treatment is selective flotation,¹³ and the lead and zinc concentrates are shipped by truck to the railroad at Tonopah.

¹³For a description of milling operations see Blackburn, W. H., Milling methods and costs at the lead-zinc concentrator of the Treadwell-Yukon Co., Ltd., Tybo, Nevada: U. S. Bur. Mines Information Circ. 6430, March 1931.

The principal workings are along the 2 G fault. Limestone forms the footwall throughout. The limestone forms the hanging wall of the fault in the underground workings, though on the surface, in the shaft the shale of the Tybo formation crops out on the west side of the fault. The overturned relation is such that the limestone which is in shale to a point 170 feet south of the shaft enters limestone, the contact dipping 60° NV. No dykes have been intruded along the 2 G fault, and though the limestone in both the porphyry and the limestone, the large bodies appear to occur within the shattered and crushed and altered rocks along the fault the limestone and sericitized porphyry is difficult to follow on the ground, and as the reconnaissance nature of the work does not permit detailed mapping, the accompanying map shows only the areas of porphyry that were recognized. The work is supported by data supplied by Mr. G. H. Barnett. Further work would probably show a wider distribution of the fault, particularly adjoining the mineralized zone. It has also been encountered in several crosscuts at various distances from the fault. In the crosscuts, although the limestone is sericitized and calcitized and carries disseminated pyrite it is less altered and consequently more readily followed along the 2 G fault.

Mineralization was not continuous along the fault. In the drifts follow only a zone of crushed rock and where, instead of ore, coarse white calcite and pyrite of pyrite may be present. For the whole development along the 2 G fault, however, about half showed either stope or appreciable amounts of low-grade sphalerite. The larger proportion of stoped ground is at the foot level as compared with the lower levels was due to the fact that this level is approximately the base of oxidation, and the oxidized ores mined above are very rich in silver.

The 300 and 710 levels have been carried further than the other levels. On the 300 level two branches have been developed, both of which have been stoped. They correspond to the two branches noted on the map and they indicate a rather gentle westward pitch. Both these branches end against a fault with a westward on which there has been postmineral movement.

ck gouge. This fault is correlated with the Uncle Sam fault, the position agrees fairly well with the outcrop of that fault. ar the west end of the 710 level, on the other hand, a strongly rked fault of approximately the same strike has a steep east-y dip, but inasmuch as the average dip, as shown by the closely rresponding positions of the fault on the surface and on the 0 level, must be nearly vertical, this reversal of dip is probably al, and this also is possibly the Uncle Sam fault.

Thus far development work west of this fault has revealed no finite vein, although small stringers carrying galena have been countered. In the ground west of the fault on the 710 level ere is considerable shale and shaly limestone. This is in gen- al characteristic of the upper rather than the lower part of the gonip limestone in this region and may indicate that the work re is within the block which at the surface shows the outcrop the Lone Mountain dolomite, between the Dimick and Gilmore ults. If so there must have been a considerable horizontal com- ment to the postmineral movement on the Uncle Sam fault, ving the Dimick fault an average lower dip and bringing its rsection with the Uncle Sam fault at this level to the north the intersection of the 2 G and Uncle Sam faults—the reverse conditions on the surface.

Postmineral movement is evident in places along the 2 G fault, rticularly in the western part of the mine, near the Uncle Sam ult. There are also several small postmineral faults which dis- ace the 2 G fault and its accompanying ore. On most of these ults the offset is not greater than the width of the drift. A rger fault with southeast dip, which crosses the 2 G fault a ort distance west of the Hales shaft on the 300 level and east the shaft on the lower levels, displaces the eastern segment of e vein to the north. This fault might be interpreted either as a rverse fault or as a normal fault with a large horizontal com- ment. Although there has been postmineral movement along is fault, the fact that on the 560 and 710 levels it definitely nits the ore body to the east suggests that part or perhaps most the displacement may be premineral. A fault zone west of the G shaft cuts the ore-bearing fault, displacing the western seg- ment to the south.

A fault apparently about parallel to the 2 G fault was cut in e Hales shaft between the 400 and 560 levels. This fault is rscribed as a fractured zone 12 feet wide, carrying a little ore. The best ore in the lower levels has been found east of the

Hales shaft. The drifts in this part of the mine are in the area which on the surface shows a split in the large mass of porphyry at the junction of the two faults.

The large body of porphyry that is intruded by the Sam fault lies a short distance to the north of the end of the 710-foot level.

Abundant flows of water have been encountered. Most of the water enters not along the 2 G fault but through fissures in the walls encountered in crosscuts. The flow of water amounted to 500 gallons a minute. If additional crosscutting had been done, the amount of water would have been appreciably less.

DIMICK MINE

The Dimick mine (Plate 3), now owned by the Tybo Co., Ltd., was not accessible at the time of visit. It was accessible at the time the examination was made. The owners are shown in Plate 3.

The lode follows the Dimick fault, which in turn has Pogonip limestone on the north and massive Lone Mountain dolomite on the south. Narrow, brecciated porphyry occur in places along the fault. The dip, as indicated by the shafts and prospecting, averages about 78° N., but a flattening in depth is suggested by the mine map.

The principal known workings extend from the surface and lie beneath Air Shaft Ridge. The air shaft is at the end of a small calcite vein with steep southerly dip. The shaft is at depth with the workings on the northward-dipping side.

It is not known how extensive were the workings on the Dimick shaft, 200 feet east of the Whim shaft. The shaft is on the map to the east of the shaft apparently without any vein.

The production of the mine is unknown but was considerable. Specimens from the shaft dumps show considerable calcite and where the vein crops out farther west, near Air Shaft Ridge, it consists of coarsely crystalline calcite with a maximum width of 15 feet. It is possible that pressure on the Uncle Sam fault has depressed the ore and that exploration of the Dimick fault in depth would be desirable.

Small, steeply dipping calcite veins have been found in places on Air Shaft Ridge.



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GILMORE MINE

The Gilmore mine, now owned by the Treadwell-Yukon Co., is on the Gilmore fault, which shows shale and sandstone of the Gilmore Gulch formation on its footwall and dolomite of the Mountain dolomite on the hanging wall. The thin-bedded Gilmore Gulch formation shows steep dips, due to drag, immediately adjoining the fault, but the dolomite on the hanging wall is massive and structureless.

Near the tunnel portal there is a solution breccia along the fault, largely within the fissured dolomite on the hanging wall. This breccia contains pebbles and boulders of dolomite, limestone, and porphyry but is itself fissured and iron stained.

No porphyry has been intruded along the fault plane, but a small mass cuts the Gilmore Gulch formation a short distance to the south.

The workings on the hillside east of Gilmore Gulch appear to have followed streaks of oxidized material within the fault zone rather than a definite vein along the fault, and also a branch fissure with vertical dip which strikes about N. 60° E. These fissures have been stoped in places, but the production is unknown. A crosscut from the Dimick workings driven by the Treadwell-Yukon Co. cut the Gilmore fault below Gilmore Gulch. Here ore of the usual mixed sulphide type was encountered. As there was no mineral movement along the Uncle Sam fault, it is possible that the productive horizon along the Gilmore fault may be depressed relatively to that of the 2 G fault.

A prospect on the Gilmore fault west of Gilmore Gulch shows only coarse calcite.

BUNKER HILL MINE

The shaft of the Bunker Hill mine, now inaccessible, lies near the extension of the Bunker Hill fault, projected southward close to the Uncle Sam fault. The surface workings indicate that the fault dips about 83° SW., whereas the Bunker Hill fault on the hillside 1,200 feet to the northwest has an apparent dip of 70° NE. The mine is reported to have been a producer in the early days of the camp, but nothing is known as to the occurrence of the ore. About 1,000 feet N. 23° E. of the Bunker Hill shaft a mineralized fault plane that strikes N. 80° E., dips 75° N., and carries calcite and limonite, has been penetrated. A tunnel 100 feet to the east follows for 100 feet a two-foot zone in a shattered porphyry dike. Along this zone manganese oxide, probably originally present as a carbonate, has replaced the porphyry. The dike is N. 60° E. and the dip 70° N.

CUNNINGHAM PROSPECT

The workings of the Cunningham prospect are part of the district, on the Dimick fault and hanging wall.

A tunnel south of the road at the west end follows the Dimick fault, which here strikes 73° NE. Quartz latite forms the footwall and the hanging wall. A vein of coarsely crystalline fault. This vein is narrow and poorly marked but widens at the face. A short distance east the calcite vein has a width of 10 feet.

North of the road the same fault, here by latite and the Lone Mountain dolomite, has by fissure parallel in strike but with vertical dip in stone north of the road has been the site of now largely inaccessible. This fissure is mainly limonitic zone and in places by a solution by fragments, itself fissured. A little oxidized s have been obtained from these workings.

BRESNAHAN PROSPECT

The Bresnahan prospect is on the north side about a mile east of Tybo.

The country rock is the Swarbrick formation consists of thin-bedded quartzitic shale and dark This rock is crossed by a fault, probably not of importance, which strikes N. 50° W. and dips

Mineralization followed a 20-foot shear zone and for the most part consisted of a replacement rock by fine-grained calcite. In places there of coarsely crystalline calcite, and at one place posed of limestone fragments cemented by calcite. The only ore mineral is sphalerite, very brown in color, in contrast to the nearly black Tybo mine, and has a high content of silver. small shoots along the fault, associated with

Development work consists of two tunnels, feet long, and a shaft.

KER PROSPECT

The Ker prospect is on the north side of Tybo half a mile below the camp of Tybo. The country Swarbrick formation, consisting of gray calcite strikes N. 25° E. and dips 50° NW. A shear zone out notable faulting, which strikes N. 70° V

has been followed by a 50-foot tunnel. Midway along this tunnel a lens 20 feet in length and 2 feet in maximum width, in which the crushed slate has been irregularly replaced by galena.

LARSH PROSPECT

The Larsh prospect is just north of the main road from Tybo, about half a mile west of the camp.

The country rock is thin-bedded platy limestone of the upper part of the Swarbrick formation. This rock is cut by a shear zone that strikes N. 62° W. and dips 82° S. Along this zone there has been irregular replacement by sooty manganese oxide with manganite and some quartz and calcite, said to have a high silver content.

The prospect is developed by a shaft, which was inaccessible at the time of visit.

RESCUE PROSPECT

The Rescue prospect, on the east front of the range nearly a

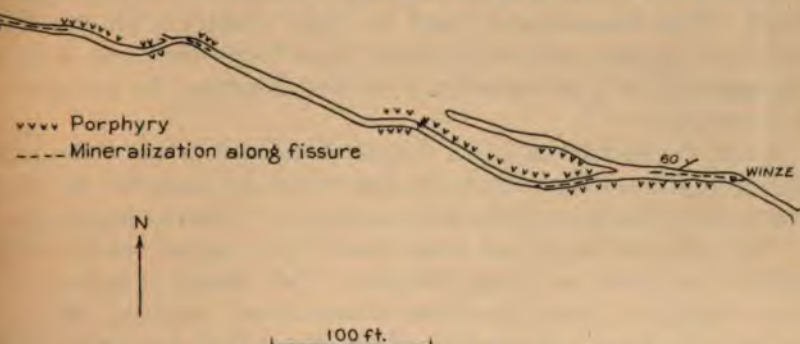


Figure 8—Map of principal tunnel, Swarbrick prospect.

mile south of Tybo Canyon and about 1,000 feet southeast of the Swarbrick prospect, is now owned by the Tybo-Yukon Co., Ltd.

A fissure which strikes N. 65° W. and dips 70° E. is in approximate alinement with the south branch of the 2 G fault on the ridge half a mile to the east. On this fissure a small amount of sulphide ore has been obtained from a 50-foot shaft. Arsenopyrite, galena, and pyrite are the sulphide minerals. Arsenopyrite is relatively more abundant than in specimens obtained elsewhere in the district. The country rock on both walls is Pogonip limestone, here massive and highly marbleized.

SWARBRICK PROSPECT

The Swarbrick prospect, owned by the East Tybo Mining Co. (J. F. Swarbrick, Walter S. Larsh, and Bert L. Quayle), is on the east front of the range, about three-quarters of a mile south of

Tybo Canyon. The property extends from the of the range to a point a short distance east of the west, where it adjoins ground owned by the Co., Ltd.

The principal workings are along the 2 G fault a tunnel about 500 feet in length (Fig. 8) and tunnels and pits, which prospect the 2 G fault about 2,000 feet westward from the point where the fault along the front of the range.

The only production has been a shipment of ore that is said to have contained 130 ounces of and 60 per cent of lead.

The fault has here an average strike of about onip limestone forms the footwall. The upper brick formation forms the hanging wall at the the west this is overlain by the Tybo shale. At stone, shown on the map as the Hales limestone fault. This limestone is itself in fault contact shale to the east, and as no fossils were found distinguishable lithologically from the Pogoni is uncertain.

As in the portion of the 2 G fault developed porphyry dikes follow the fault, and where ore one or both walls are generally composed of she

The principal work has been done in the up follows the fault for about 500 feet. Two lens very slightly oxidized, have been encountered; of the tunnel has a maximum width of 6 inches face shows 1 to 2 inches of solid galena adjoining zone. In these lenses there is almost no gangciated with the galena. Elsewhere along the of manganiferous calcite without associated The calcite, however, is not present close to th of the distance explored the fault plane shows

A prospect about 200 feet south of the poi fault is cut off by the northward-trending fa galena-bearing vein that strikes about N. 70° W to the north. This vein also is cut off by the no the range front.

On the west face of the hill to the north a vein cuts the thin-bedded limestone. This vein strike and steep easterly dip and is traceable f

ing the outcrop. Similar smaller veins cut the limestone at north end of the hill. These veins are older than the fault which here outlines the range front, and where cut by this fault they show a surface polished to mirrorlike smoothness.

The grain of the quartz is so fine that it resembles quartzite, a few small druses are present. Small specks of limonite here and there constitute the only metallic mineral observed, but a tenor of silver is said to be present.

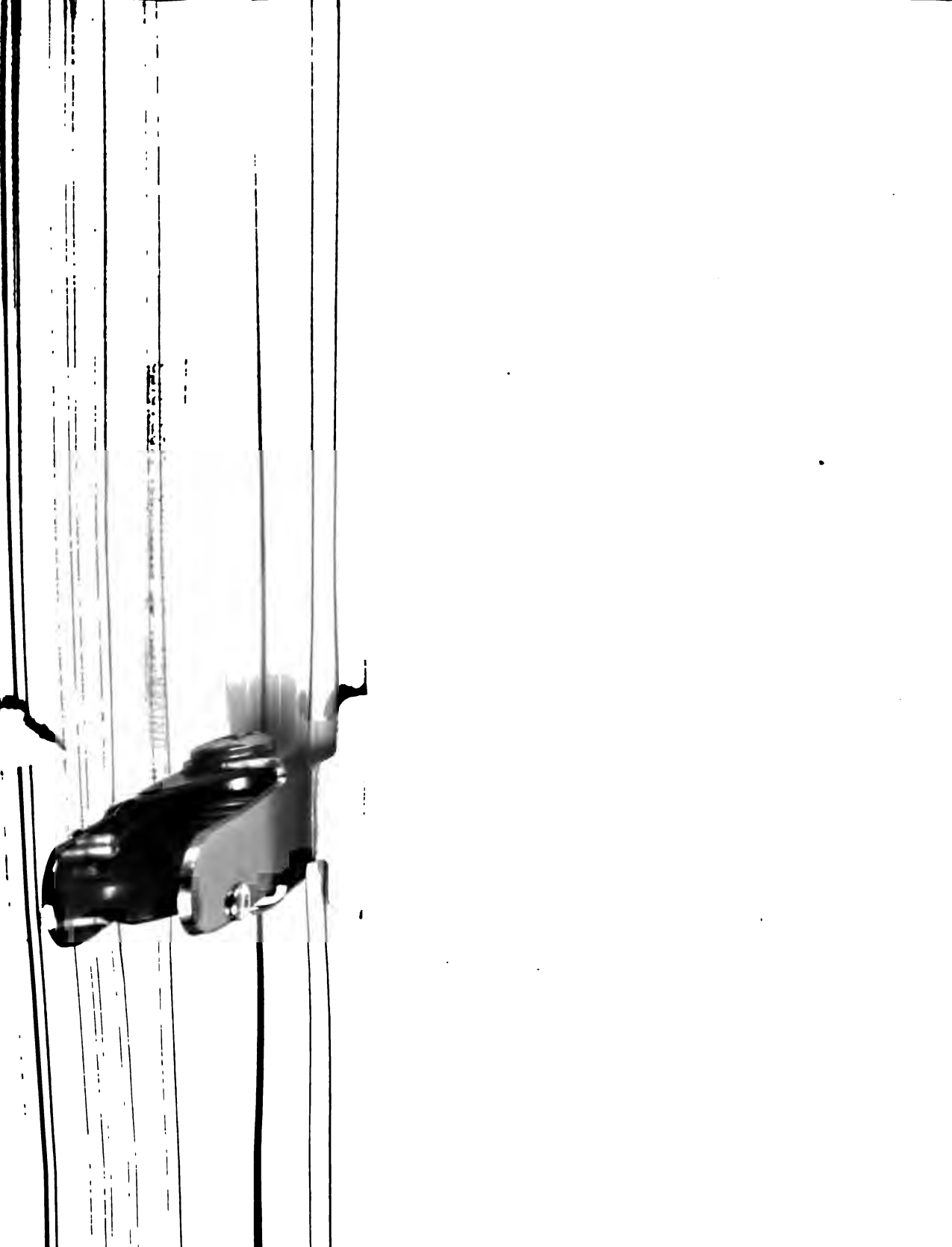
As far as could be determined these veins do not occupy extensive fault planes. The major vein, however, trends approximately parallel to the neighboring range-front fault and, though older, may have been emplaced along an earlier fissure of the same trend.



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No. 2

BULLETIN OF NEVADA STATE BUREAU OF MINES AND
MACKAY SCHOOL OF MINES

GEOLOGY OF THE TUNGSTEN DEPOSITS NEAR MILL CITY, NEVADA

By PAUL F. KERR
Columbia University
New York, N. Y.

PRICE, 40 CENTS



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GEOLOGY OF THE TUNGSTEN DEPOSITS NEAR MILL CITY, NEVADA

By PAUL F. KERR

INTRODUCTION

Mill City stands among the important tungsten producing districts of the world, and is at present the chief producing deposit in the United States.¹ In 1931 it produced 1,055 short tons of concentrates with 60% WO_3 equivalent, or about 75% of domestic production.² This amounted to approximately one-sixth the production of the Kiangsi tungsten mines in China, and about one-third the production of the Malay Peninsula for the same year. Geologic studies and mining estimates indicate that large reserves are available to considerably increase this production and it is estimated by the operators that in normal times, with reasonable prices, sufficient concentrates could be produced to care for the demands of the United States.

The tungsten occurs in scheelite associated chiefly with quartz, garnet and epidote. The ore bodies are vein-like in form but have been produced by contact-metamorphism of thin limestone members in a siliceous sedimentary series. The associated sediments have been metamorphosed to hornfels, slate and quartzite. Extreme deformation, faulting and fracturing have separated the ore bodies into isolated nearly vertical segments arranged *en echelon* along a bearing of about N 20° E.

The contact metamorphism responsible for the ore is believed to be due to the intrusion of granodiorite. The later stages of intrusive action appear to be most closely related to the crystallization of scheelite. Progressive stages in the metamorphism of the limestone strata may be interpreted from detailed studies of various parts of the area and criteria are available to determine the mineral sequence.

During the summer of 1932 an opportunity was offered to examine the deposit in considerable detail. Both an underground

¹Hess, Frank L., Tungsten; Minerals yearbook, U. S. Bur. Mines, 1932-1933, p. 271-279.

²Fink, Collin G., Tungsten, Min. Ind. 1931, p. 559.

LOCATION AND HISTO

The tungsten deposits are located at the Tungsten (elevation about 5,000 feet), eight City, Nevada (Figures 1 and 3). Tungsten eastern slope of the Eugene Mountains (U. S. map, Lovelock quadrangle), and is connected with the highway at Mill City. Mill City transcontinental line of the Southern Pacific Victory Highway, 145 miles northeast of Reno.

A map showing the location of the mine workings is shown in Figure 2. The area shown in the working mines and important prospects district town of Tungsten, and shows their location the granodiorite intrusive. Three rounded ing canyons form the most prominent landmarks and are known as Stank Hill (Figure 4), Springerboldt Hill (Figure 5). The three most important similar names and extend beneath the hill of Codd. The mine workings reach a depth of 600 feet in the mine and 800 feet in the Stank mine. Drifts northeast-southwest to north-south along segments of replaced limestone beds. The extreme the opposite ends of the workings is about one ing are by no means continuous for the entire the granitic intrusion intervenes for approximately between the Springer mine and the Stank mine.

A small mine, the Summit mine (Figure 4) of Stank Hill, was worked for a time, but has several years. The Codd mine, south of the presumably a continuation of that ore body, ore, but is also abandoned at present.

Among the most promising of the deposits present time but offering possibilities of future the Sutton ore body (Figure 6). The Sutton north-south on either side of the town of Tungsten the area included in the map. Exploration body has never been completed, although ore isolated places throughout an extent of two miles mining operations have been carried on in the Altogether, approximately 1,000 feet of tunnels

mining operations throughout the recent development, and is thoroughly familiar with all of the workings, including portions no longer accessible. He has been particularly considerate in going over the underground workings and in discussing the mining development in its relationship to the geologic features. The writer is also indebted to Mr. Powell Thompson for assisting in the preparation of the topographic map (Figure 7), and to the Stanford Geological Survey for the topographic base, upon which the map (Figure 2) has been drawn.

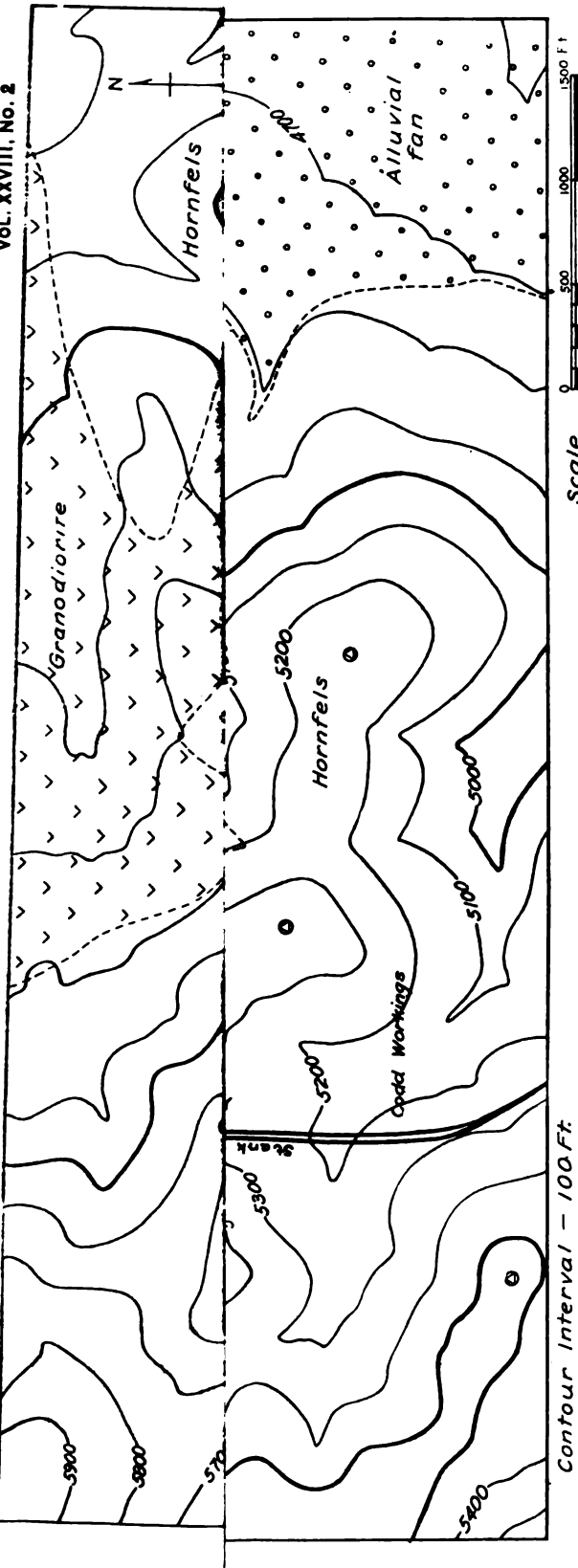


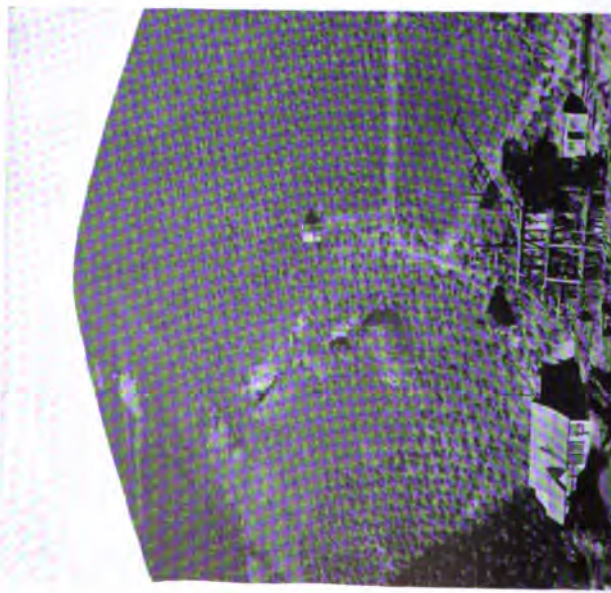
FIGURE 2. A general map of the mining district of Tungsten, showing principal scheelite bearing deposits and position of intrusive granodiorite.



back-



cated
stank
stank



have been dug in prospecting two closely parallel limestone beds that constitute the Sutton ore body.

The tungsten deposits at Mill City were discovered in 1917.⁴ In 1918 two mills were built—one by the Nevada-Humboldt Tungsten Mines Company, the other by the Pacific Tungsten Company. In 1926 the Nevada-Massachusetts Company took over the Pacific Tungsten Company and later acquired the Humboldt Tungsten mine. All of the claims in the group are now owned by the Nevada-Massachusetts Company. The property was in continuous operation from the time the Nevada-Massachusetts Company entered the business until 1932, when production was suspended from May to December, due to the lack of a market. A staff was kept on hand, however, in order to improve the mill and keep the mine workings in order. Advantage was also taken of the suspension of operations to install a new headframe and ore bin at the Humboldt mine. Mining was renewed in 1933, and operations have been continued at full capacity since that time. Over 20,000 tons of ore are reported to have been milled from the tungsten deposits at Mill City in the last eight years, and it is estimated by the management of the property that 2,000 tons of high grade scheelite concentrates could be produced per annum. Until 1932 the normal ore contained about 1.10% scheelite. During that year, however, new discoveries were made which materially increased both the quality and the quantity of the ore reserves.

The ore ordinarily consists of fine-grained scheelite disseminated through a groundmass consisting largely of garnet, epidote, quartz and calcite, with scattered crystals of pyrite. A bulk concentrate consisting of garnet, scheelite and pyrite is produced on the place. The garnet is removed by means of a magnetic separator, and the pyrite by flash roasting and magnetic separation.⁵ The concentrates are used in the production of tungsten steel, and all within the following specifications:

WO ₃	65-70%
Tin maximum.....	(trace)
Copper maximum.....	0.05
Sulphur maximum.....	0.75
Phosphorus maximum.....	0.05
Arsenic, Antimony and Bismuth, not over.....	0.035 each

The concentrates carry four to six ounces of silver and a trace of gold per ton, but no effort is made at the recovery of precious metals.

⁴Heizer, Ott F., U. S. Bur. Mines, I. C. 6284, June, 1930.

⁵Heizer, Ott F., U. S. Bur. Mines, I. C. 6280, June, 1930.

GENERAL GEOLOGY

The general geological relationships are shown in Figure 7. Two principal formational units are the metamorphosed sedimentary series and an intrusive granodiorite. The map indicates the outcrop portions of the sedimentary series and the projection of the strata. Scheelite bearing rocks along the strata are also indicated.

In addition to the main igneous area, isolated small intrusive masses of granodiorite are shown. Care has been made in mapping to distinguish the diorite from the granodiorite intrusion. A few dikes of hornfels are indicated, but do not belong to the granodiorite intrusion.

SEDIMENTARY SERIES

The sedimentary series in the vicinity of the tungsten deposit has an indefinite thickness, and it is uncertain whether the beds are normal or reverse in attitude. Metamorphism has obscured many of the original sedimentary structures, and deformation has been intense, the average dip of the strata being about 70°. Part of the sedimentary series is Triassic, although several thousands of feet of younger sediments may be much younger in age. A fossil, *subcircularis* (Gabb) was identified by Dr. Simeon D. Henshaw in strata south of the mill at Tungsten.

Several types of metamorphosed sedimentary rocks occur in the Eugene Range. In the vicinity of the ore body the rocks are at present chiefly hornfels, although quartzitic rocks are in evidence. A slaty phase occurs in several places. The slaty character of the rock appears to be accentuated by surface weathering. Underground the same strata are free from rock cleavage.

Erosion has removed the sedimentary cover in many places, exposing portions of the underlying granodiorite in blocks of cover rock. The contact between the cover rock is free from cleavage to such an extent that fractures are not across the contact rather than parallel, and numerous specimens may be collected with granodiorite on one side and the other.

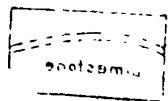
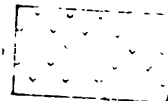
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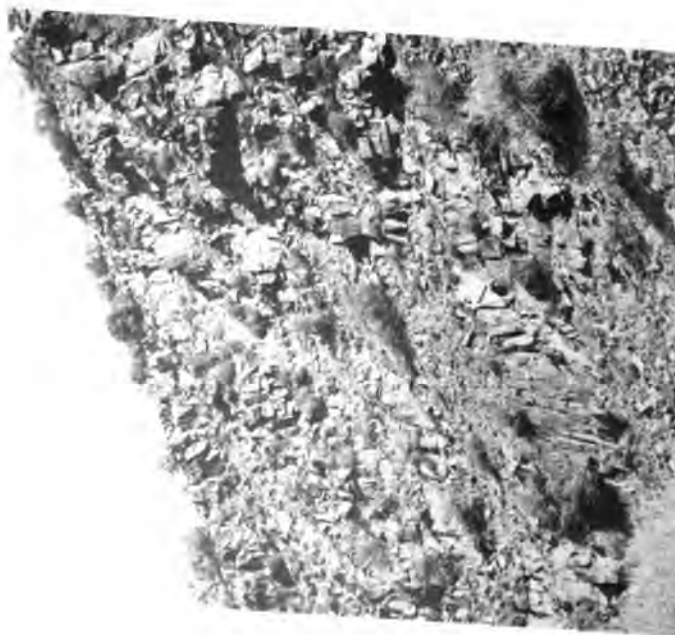


HORNFELS

The hornfels is a hard, extremely tough, olive-green or light gray rock which changes to brown on weathering. It is badly fractured, with joint planes extending in all directions (Figure 8). It weathers to rough angular blocks scattered loosely on the rounded surfaces of hills. Color bands in the rock frequently indicate the original planes of bedding and yield the most reliable criteria available for determining the attitude of the strata. Hillsides underlain by hornfels may be frequently distinguished at a distance on account of peculiar rock streaks due to the concentration in straight vertical lines of small joint blocks (Figure 3). These streaks are from two to six feet in width, extend straight downward drainage lines on rounded hillsides, and are arranged radially around the crest. They consist of shallow rock-filled depressions and contain virtually no soil. The rock blocks are usually from one to six inches in diameter and have been loosened from the hillside by storm action. The hornfels is so largely quartz that very little soil is produced, and any soil formed may be easily washed away during cloudbursts. It appears probable that the rapid erosion of desert storms concentrates these blocks and removes the soil. Frequently blocks are so angular and well formed that they appear on casual observation to imitate crystal forms. Such a joint block is shown in Figure 14. This block exhibits nine fracture planes, no two of which are parallel, and furnishes a fair illustration of the complexity of the fracture pattern.

Earlier fractures in the hornfels have been filled in places with quartz and also with epidote. Later fractures are open. During metamorphism thermal solutions evidently penetrated the sedimentary series in all directions. Thin sections demonstrate that much of the rock has been recrystallized and now consists for the most part of a fine mosaic of quartz and actinolite, varying in places to a quartz-biotite mixture (Figure 24). Fine cordierite, epidote, zircon, rutile, and pyrite occur as accessory minerals. The microstructure of the rock is commonly poikilitic with quartz, amphibole or mica.

In places black bands three or four feet thick occur intercalated with light greenish layers. The black layers consist of microscopically fine elongated hornblende crystals in random arrangement in quartz. The surrounding layers are composed of fine needle-like aggregates of the same material in a quartz groundmass. On the whole, the sedimentary series, aside from the host rock members, is comparatively free from concentrations



of epidote and garnet. The garnet and epidote are confined to small segregations in intensely silicified areas, to small veinlets, and to extremely fine, isolated microscopic crystals occasionally found along the old bedding planes.

The intensity of the silicification in the hornfels appears to have been greater in the vicinity of the present prominent hills, and it is not unlikely that Humboldt Hill, Springer Hill and Stank Hill may correspond in a general way at least to more intense zones of silicification in the sedimentary series. Intensity of silicification may be in turn connected to intensity of the contact metamorphic action resulting in the crystallization of scheelite. Thus the highly silicified hornfels of Humboldt Hill, Springer Hill and Stank Hill may be a natural accompaniment to the ore formation at the adjacent mines.

LIMESTONE

Limestone strata occur in isolated beds at irregular intervals in the hornfels. The strata have the same attitude as the hornfels above and below (Figure 9). The best limestone exposures near the mines occur along the ridge west of Stank Hill.

The beds in the area studied may be divided into two groups separated by the Stank fault, as shown on the map (Figure 7). One group occurs west of the Stank fault, and throughout this group the effects of contact metamorphism have been less severe at the surface (Figure 27). The second group occurs east of the Stank fault, and throughout this group contact metamorphism has been extensive and the beds have been largely replaced. The beds of the second group contain the principal high grade ore.

The beds east of the fault vary from 3 to 15 feet in thickness, though the normal thickness is from 3 to 6 feet. Faulting has been pronounced and the beds have been broken into so many fragments that it is not certain whether two or three parallel

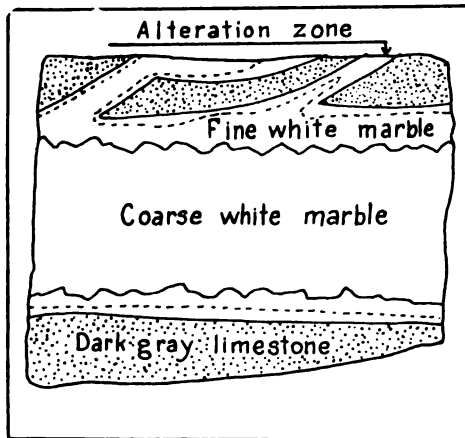


FIGURE 10. Diagram illustrating the original dark gray limestone bounded by an alteration zone and fine white marble. The fine white marble has been penetrated by coarse white marble.

beds occur. It seems certain, however, that and there is a probability that several isolated on the surface belong to a third bed.

West of the Stank fault nine beds may be area mapped (Figure 27). These appear deformed portion of the area, and several considerable distance by means of occasional tered pieces of float occurring on the soil or more prominent limestone beds measure from thirty-three feet, and six feet in thickness and

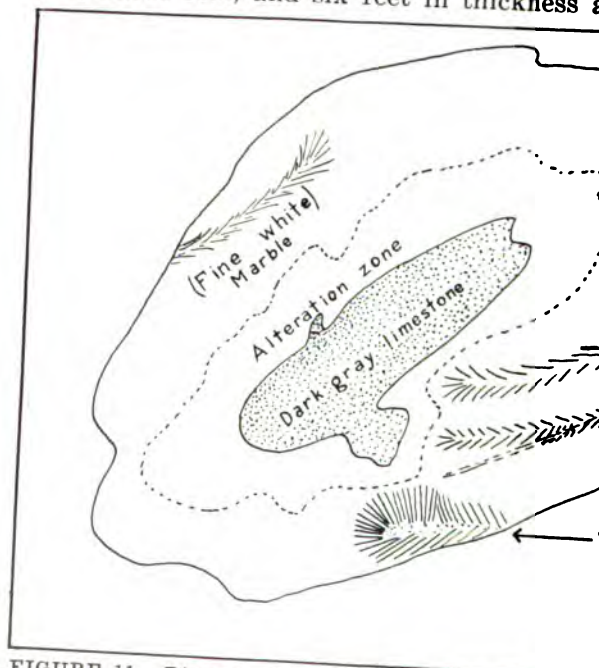


FIGURE 11. Diagram showing the alteration of dark limestone with the subsequent formation of white marble being penetrated by radial wollastonite and cut in

thickness to permit profitable mining if mineral fifth, the summit bed, shows mineralization at the far no exploration has been made to determine metamorphism below the surface in buried portions stone beds nearer the underlying granodiorite. that at some time these beds will be prospective scheelite. A crosscut normal to the strike or holes from the Stank workings intersecting the at depth should indicate the extent of mineral beds parallel to the Stank ore body.

The limestone is commonly blue-gray in color, although in some exposures it is almost black. It usually weathers to a light gray color, and several outcrops show a ribbon-like brown and gray banding due to weathering. Some of the strata are also somewhat sandy. The color of the limestone is probably due to a large amount of included carbonaceous matter. Small tremolite crystals are also widely distributed (Figure 21). These crystals occur in the beds west of Stank Hill and may indicate an increase in the magnesium content of certain of the limestone strata.

Contact metamorphism appears to have produced an alteration of the limestone by stages. First a greenish-white alteration zone

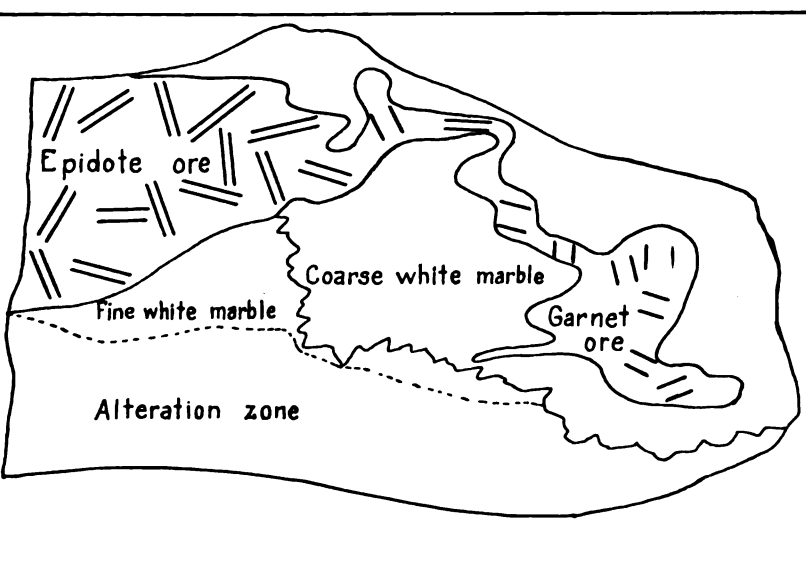
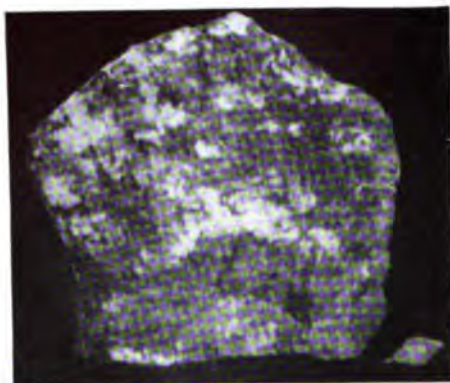


FIGURE 12. Diagram showing epidote and garnet (dark brown variety) invading coarse white marble.

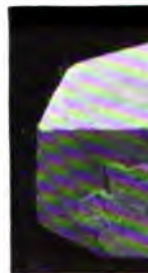
has been produced (Figure 10) with the accompanying destruction of the dark gray limestone. Numerous examples of dark gray limestone remnants entirely surrounded by the greenish alteration zone occur in the vicinity of ore bodies. Following the greenish alteration recrystallization to fine white marble occurred, frequently accompanied by the formation of white fibrous wollastonite (Figure 11). The final stage in the metamorphism resulted in the formation of coarse white marble accompanied by the introduction of garnet or epidote (Figure 12).

Tremolite appears to be replaced during this metamorphism and carbonaceous matter entirely disappears, no graphite being

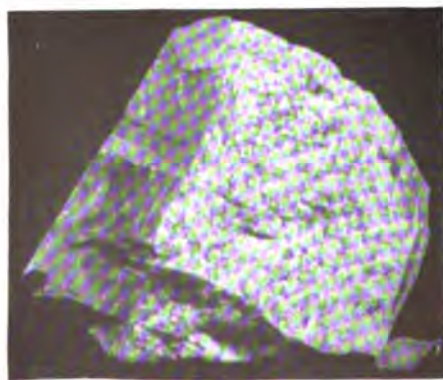


F
Scheelite
groundmass.
size.)

FIGURE 14
Fracture block of hornfels. (One-third
natural size.)



F
Portion of
granodiorite
ral size.)



formed. Ore has not been found in the gray portions of the limestone beds, and it is only where the limestone has become altered to marble that the ore-bearing mineralization occurs. Numerous remnants of gray limestone, however, occur in the mineralized portions of the beds.

THE ORE BODIES

The principal ore bodies including the Humboldt-Springer and Stank ore deposits are distributed along the western margin of the granodiorite intrusive (Figure 2). The Sutton beds, not worked at present, lie in a position more or less parallel to the main ore bodies, but on the east of the intrusive. For the most part the surface exposures of the ore are restricted to an area within 2,000 feet of the margin of the intrusive, as outlined on the areal map (Figure 7). The ore values, however, vary considerably, even within this limited area. It is only in cases of unusual concentrations that extremely high grade ore is found, and these may occur either immediately adjacent to the igneous mass or considerably removed from it. Portions of the replaced beds may be found in contact with the granodiorite, either terminated by the granodiorite mass or cut by intrusive dikes.

The thickness of the ore body is usually uniform in an individual bed (Figure 9). Beds now worked are normally about five or six feet thick and continue with only minor variations in thickness for distances of several hundred feet along the strike. In places the ore zone is twice the normal thickness, due to faults of 10 to 40 feet displacement that cut the strata at an angle of about 5° to the strike. Where the beds are mineralized there appears to be little change in ore value with depth. In the southern part of the Stank workings, however, the ore values have been better at the lower levels, apparently because the mineralization has been more intense.

The outstanding characteristics of the mineralized beds are a prominent display of the contact metamorphic minerals garnet and epidote, together with an unusual concentration of vitreous quartz. The scheelite is obvious to the eye in only a few places in particularly high grade portions of the deposit. Elsewhere it appears as minute specks disseminated through the garnet and epidote. Other minerals occur in the ore beds, but garnet, quartz and scheelite are the most prominent. The contact, metamorphic product, consisting of masses of contact metamorphic minerals formed in limestone has been called "tactite" by Hess.⁶

⁶Hess, F. L., Tactite, the product of contact metamorphism. *Am. Jour. Sci.*, 4th ser., vol. 48, 1919, pp. 377-378.

Several types of ore are distinguished in the deposit. These may be described as garnet ore, garnet-quartz-epidote ore. The garnet ore occurs near the Stank mine and to a lesser degree in the Humboldt mines. Garnet-epidote ore is distributed throughout the entire deposit and may occur with either of the other types. The highest grade ore concentrations belong to the garnet-epidote type, as illustrated in Figure 13. The high grade ore contains much scheelite in both the garnet ore and garnet-epidote ore. The ore is usually highly silicified and appear glassy.

In the lower levels of the Humboldt mine and in the Stank mine the ore has been pulverized by metamorphism. Powdered ore of this type is dark gray and contain as much scheelite as uncrushed ore in the upper part of the deposit. A slip zone is frequently encountered in the hanging wall within a few feet of the unmetamorphosed ore. There is no parting, however, between the mineralized zone and the hornfels.

The best ore values appear to favor the garnet-epidote vein-like bed. The complete bed is not always present. The high-grade portions of the deposit, but where they are not taken place no ore values are found.

MINERALS PRESENT IN THE ORE

CALCITE

Calcite may be found in the ore beds in a variety of forms in which it occurs in the region, varying from gray limestone to the most highly metamorphosed recrystallized marble. Portions of the gray limestone containing carbonaceous matter occur in the ore beds as remnants that have not been replaced. In the occurrence in the gray limestone, calcite occurs as coarse white marble, in secondary euhedral crystals in cavities. Apparently all of the deposit is calcite. Qualitative tests show that the amount of magnesium and all of the X-ray diffraction taken of different types of carbonate have been observed. Dolomite and magnesite have been observed.

The significance of the importance of calcite and calcium in the crystallization of scheelite may be seen from the fact that all specimens of ore that have been obtained small amounts of that mineral.



FIGURE 16. Resistant granodiorite knob due to silicification in veins, surrounded by weathered granodiorite east of Humboldt Hill.



FIGURE 17. An outcrop of hornblende-andesite in contact with hornfels. Hornblende-andesite above white line, hornfels below.

Figure 20 illustrates an isolated patch of scheelite in a groundmass of quartz. It is a small, irregularly shaped, light-colored mineral that has replaced part of the calcite in the scheelite-calcite mixture suffered invasion and

TREMOLITE

Two varieties of tremolite are found in the area. The first is widely separated from the standpoint of origin. The first is early tremolite that occurs in small, irregularly shaped crystals in an irregular arrangement throughout the gray limestone. Tremolite crystals have been found in abundance in the beds more than a mile from the nearest tungsten deposit. The crystals show characteristic rhombic cross-sections in thin section, and fragments have been found with properties for tremolite. In addition, small fragments of limestone have been concentrated by treatment with hydrofluoric acid. The diffraction patterns of the concentrated residue and compared with X-ray diffraction patterns of several known localities, making use of the standard comparison for identification.⁷

The second tremolite is radial tremolite that occurs in association with actinolite, apparently formed by the replacement of solutions following the main contact metamorphism. The early tremolite is restricted to the gray limestone, while the late tremolite occurs in minor amounts in the white marble. The late tremolite is fibrous and occurs in contrast to the isolated small crystals of the early tremolite. It does not appear to be a residual of the early tremolite.

WOLLASTONITE

Wollastonite occurs in streamers and radiating aggregates (Figure 11). These are snow-white in color, and occur in the fine white marble. The mineral does not occur in the coarse white marble phase. It is present in the coarse white marble phase. It is present in the fine white marble that have been produced by the replacement of the gray limestone and have not yet suffered replacement by the coarse white marble. It is probable that the early mineral produced at a stage prior to the formation of the main contact metamorphic minerals, garnet, scheelite.

GARNET

Several types of garnet may be found in the area. It occurs as a light pale pink mineral in association with the

⁷Kerr, Paul F., *Econ. Geol.*, Vol. XXVII, No. 7, November 1932.

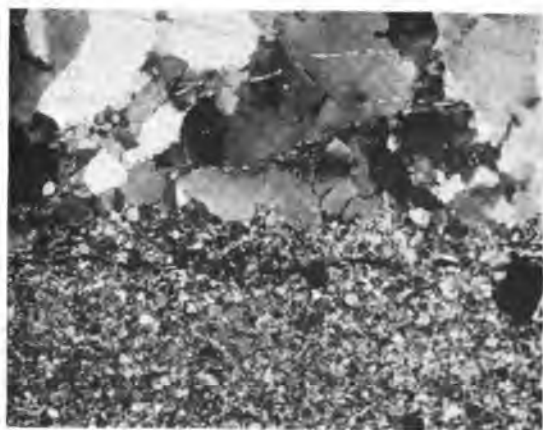
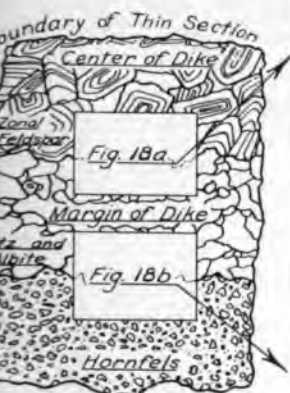


FIGURE 18

Phases of the granodiorite intrusion (photomicrograph x 20).

(a) Central portion of a dike showing zonal feldspar.
(b) Quartz-albite margin in contact with hornfels.

aggregates of wollastonite apparently formed as a result of the limestone. Garnet of this type does not occur associated with scheelite, and no epidote occurs anywhere. It is usually found in areas immediately adjacent to the patches of gray limestone and is assumed to be a product of deposition.

Reddish-brown garnet, probably grossularite, occurs in some parts of the deposit (Figure 26). Garnet of this type is associated with scheelite. A very dark brown garnet, grossularite andradite, occurs in the middle of the Stank mine. It is associated with molybdenite (Figure 25). It appears that this garnet is of earlier origin than the grossularite.

In thin sections the various varieties of garnet show an anomalous birefringence between crossed nicols. This is due to garnet formed by replacement of calcite due to contact metamorphism.⁸ All types of the garnet in the deposit belong to the "ugrandite" series of Winchell⁹ and the phenocrysts of garnet fringence does not appear restricted to any particular type. X-ray diffraction photographs of grossularite and andradite from ore beds have been taken. Both appear to be isotropic. This is in spite of the anomalous optical properties.

EPIDOTE

Epidote is found in interlacing crystals that vary from microscopic grains to crystals a quarter of an inch in size. Some about an inch in length. Such crystals are usually associated with quartz (Figure 22) or protrude from the walls of the mine. Another form of epidote of much finer crystalline texture occurs as a later phase. This type of epidote consists of disseminated crystals scattered through quartz, and gives the rock an olive-green cast to the rock. Microscopic evidence of the coarse generation of epidote being broken down by the fine-grained second generation is abundant. This appears to be associated with both generations. It is probable that the coarse high grade concentration of epidote occurred with the second generation. The coarse epidote and scheelite in the Humboldt mine are found suspended in an epidote-quartz matrix made up of finely disseminated epidote scattered through the quartz with traces of molybdenite (Figure 23).

⁸Illustrated in Rogers, A. F., and Kerr, I. F., *Thin Sections of Minerals*, McGraw-Hill, New York, 1933, p. 118, fig. 113.

⁹Winchell, A. N., *Elements of optical mineralogy*, John Wiley & Sons, New York, 1927, p. 257.

SCHEELITE

Scheelite occurs in pure white imbedded crystals with a characteristic greasy luster. The crystals vary in size from a fraction of a millimeter to several centimeters in diameter. Scheelite is frequently not easily seen in the ore even in high grade specimens. The miners often wet the surface of the rock in order to make the mineral stand out from the quartz. The scheelite fluoresces bluish white in ultra-violet light.¹⁰ An excellent effect is given by scheelite subjected to the radiation from a spark gap arc. Recently an ultra-violet light installation consisting of an iron spark gap arc operating on a high voltage transformer and utilizing a mica plate condenser has been found to have practical value. It is useful both for the examination of mill products and in the study of the ore.

Although the normal color of the scheelite throughout the deposit is white, a few samples of coarse crystallization have been found in the Stank mine in which the scheelite is pale brown. In the bed west of Springer Canyon yellow scheelite occurs, the color probably being due to traces of tungstite.

Scheelite is for the most part anhedral or subhedral in form (Figure 19) and is not found free from a matrix of embedding minerals. As previously stated it is usually associated with quartz, calcite, epidote or garnet.

ACTINOLITE

Actinolite is not only a prominent constituent of the country rock, but is found throughout the ore body. In the ore beds, however, it appears to have been formed as a later mineral, following the crystallization of the coarse epidote and scheelite. It may have been in part contemporaneous with the crystallization of the fine epidote and part of the scheelite. On the whole, however, it appears to have been somewhat later than the minerals previously mentioned.

ZEOLITES

The most prominent zeolite found in the deposits is stilbite. It occurs in radial aggregates and in plates. Stilbite is found as vein-filling material along the cracks and fissures in dikes and within the ore body. It was probably crystallized at a late stage following the crystallization of the intrusive mass. In

¹⁰Scheelite from Mill City was not examined by Van Horn in his study of fluorescence. The fluorescence of the Mill City scheelite, however, is similar to the effect he observed in scheelite from a number of other localities. Van Horn, *R., Amer. Min. Vol. 15, No. 10, Oct., 1930, pp. 461-469.*



FIGURE 19
Scheelite in a groundmass of quartz
and calcite. (Photomicrograph x 20.)



FIGURE 20
Isolated scheelite grains.
(Photomicrograph x 20.)



FIGURE 21
Tremolite in gray limestone. (Photo-
micrograph x 20.)



FIGURE 22
Euhedral epidote in quartz.
(Photomicrograph x 20.)



FIGURE 23
epidote and calcite associated with
elite in quartz. (Photomicrograph
)



FIGURE 24
A typical thin section of the horn-
fels. (Photomicrograph x 20.)



FIGURE 25
Molybdenite (black) in garnet and
elite.

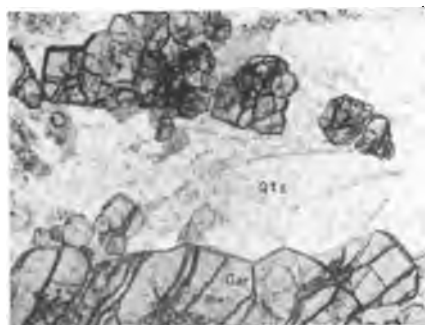


FIGURE 26
Subhedral garnet in quartz. (Photo-
micrograph x 20.)

the yellow scheelite bed stilbite occurs in tains traces of a yellow mineral, possibly also occurs in the high grade portion of the

OTHER MINERALS

Pyrite and quartz are found in profusion body and extending in all directions thro rock. Pyrite occurs in small crystals di quartz and virtually all of the other miner contact metamorphism. Quartz was formed during the mineralization, and has been rep tured, and recrystallized time and again. deposition, veins of quartz were formed cut right angles. Molybdenite and pyrrhotite constituents of the ore. Chalcopyrite specimen ally found. Molybdenite is found in a sn few feet long and about six inches in wid 300 level in the Stank mine just north of tion it is widely distributed in small am levels of both the Stank and the Humboldt

Molybdenite fills fractures, cutting the ea garnet, epidote and scheelite (Figure 25). have been reported in analyses of the conc sible that small specimens reported occasio bismuthinite.

INTRUSIVE GRANODIORITE

Granodiorite occurs both in the main int dikes extending outward and cutting the ho diorite probably underlies most of the Euge occurrences a number of miles apart may b boundaries of the mountains. In the vicini eral square miles of granodiorite are exp resting upon the granodiorite is normally veneer but is a pendant having considerab tour of the upper surface of the granodiorite ing operations, however, indicate that it is and that the sedimentary cover is much t mapping would lead one to believe. Where fels remain upon the overlying granite surf penetrated during mining operations, they extend almost vertically without interrupt feet in depth. The hornfels - granodiorite strike of the Stank ore body is probably in and seventy degrees (Figure 29). Even i

granodiorite has cut the ore bed at right angles the inclination steep. Nevertheless, in spite of the high angle of contact, it is hazardous to predict any considerable extension of the ore beds beneath the present mining levels.

The weathering of the granodiorite is apparently influenced to some extent by the abundance of quartz veinlets and fracture blocks. On the whole, the granodiorite appears to weather much more easily than the hornfels and forms the valleys, while the hornfels forms the ridges and hilltops. In a few places small pyramid-like hills of granitic rock stand out because of greater resistance to erosion due to a large number of intersecting quartz veinlets in the rock (Figure 16).

The granodiorite is an even grained holocrystalline rock composed of quartz, soda, and soda-lime plagioclase, amphibole, biotite, and accessory minerals including orthoclase. It was classified by Larsen¹¹ as a granodiorite, although further examination indicates that some phases may be more nearly a quartz diorite. Thin sections demonstrate the presence of the following essential minerals: quartz, andesine (zoned and corded), albite, hornblende (partially altered to chlorite), and biotite (partially altered to clear biotite and chlorite). The biotite also contains included zircon crystals. The accessory minerals in the granodiorite are epidote, titanite, calcite, magnetite, apatite, pyrite, zircon, leucoxene. Dikes radiate outward from the granodiorite in a number of places. These vary from less than an inch in diameter to several that are about 100 feet in thickness. The length of the dike exposed at the surface, however, seldom exceeds 300 to 400 feet.

The dikes cut all phases of the hornfels and the ore beds. They show two types of mineralization, one containing a concentration of albite and quartz which occurs along the margins and sometimes constitutes the entire dike. The other phase is the granodiorite or quartz diorite phase which makes up the centers of many of the dikes and forms the main mass of the major intrusives. The marginal portions of the dikes appear to have been forced outward from the intrusive mass either as the central phases were being crystallized or closely following their crystallization. Shear lines appear along the walls of the dikes and along the contact between the margins and the centers. The shear cracks have been filled by later quartz and are associated with quartz-albite mineralization.

It is generally recognized that soon after the solidification of

¹¹Hess, F. F., and Larsen, E. S., Contact metamorphic tungsten deposits, S. Geol. Surv. Bull. 725, 1921, p. 296.

an igneous rock the rock may be *self-injected*. The granodiorite, for example, may be invaded by an upward penetration due to end-stage emanation of granodiorite or granodiorite magma which produced the tungsten deposits. The granodiorite both in dikes and in the intrusions associated with the tungsten deposits has suffered erosion. This is apparently reflected in the topography of the area east of Humboldt Hill (Figure 16). In the deeply eroded granodiorite several resistant features are visible. These appear to have resisted erosion on account of concentration in a small area of end stage mineralization of erosion resistant quartz.

Evidence of end stage action may be observed in thin sections. Figure 18 illustrates two views (Figures 18a and 18b) are photomicrographs of a large thin section sawed at right angles to the type illustrated by Figure 15. The dike, the marginal quartz-albite area and the albite zone were all retained in one unbroken section and are shown in Figure 18. Comparison of the two photomicrographs and the key sketch in Figure 18 should bring out the

SILICIFICATION

Silicification appears to have occurred at a late stage effect of the intrusion. Presumably the quartz-albite invasion and increased as the magma cooled. Vein quartz invasion appears to have followed the quartz-albite invasion and the extensive silicification. Multiple banding of albite layers and quartz layers in some of the dikes is a relationship between the albitization and the silicification.

Vein quartz cuts across the high grade garnet bodies at right angles and it is naturally concluded that crystallization of scheelite ore occurred prior to the invasion of quartz of the quartz-albite stage, and massive quartz associated but presumably slightly later, appeared related to the ore mineralization. The massive quartz contains fine epidote crystals associated with the later veins consist of barren quartz.

Silicification appears to have been more extensive than in others. These zones do not appear to

¹²Colony, R. J., The crystallization of an igneous rock. No. 3, Apr.-May, 1923, pp. 169-178.

sedimentary series, nor are they related in any apparent relation to the intrusive contact. The west side of Humboldt Hill, the vicinity of the Baker prospect, the crest of the hill above the South Sutton workings, Springer Hill, the vicinity of Stank workings at the surface, the crest of Stank Hill and several minor localized areas appear to have been more highly silicified than adjacent areas. These zones are irregular in shape; in fact, the outlines are so obscured by gradation into normal hornfels that the zones can only be indicated and not accurately mapped. The chief significance of the zones of silicification lies in the fact that in several of the areas mentioned high grade ore deposits are found, and in all the indications of ore appear to be of economic importance. In each case in which limestone beds happened to fall within the zone of silicification dense replacement appears to have taken place.

HORNBLENDE-ANDESITE

The hornfels and limestone beds and also portions of the monodiorite are occasionally cut by small dikes of hornblende-andesite (Figure 17). The hornblende-andesite appears to be an entirely later phase of igneous intrusion, and is probably related to the processes of ore formation. The hornblende-andesite is composed essentially of soda-lime feldspar varying from extremely fine crystals to moderate-sized phenocrysts. Abundant hornblende crystals varying considerably in dimensions are scattered indiscriminately throughout the rock. The common hornblende is green, although a brown variety occasionally occurs as an alteration. The accessory minerals are magnetite, ilmenite, leucoxene, apatite, and titanite. Zonal banding is common in the plagioclase which is chiefly andesine with some laboradorite. Later veinlets of chlorite cut the hornblende-andesite in places and also penetrate the previous rocks.

STRUCTURAL FEATURES

The Eugene Range in which the Tungsten constitutes a fault block of the basin and the west side more elevated than the east. The range of importance to the mining problem is the comparatively recent displacements of the mountain block, but the complex and earlier magnitude that occur within the range.

The general strike of the sedimentary strata traces of the old lines of sedimentation is apparent. Locally the strike may vary to north-south or east-west. The entire district are badly fractured and faulted, and the fracturing is so complex that it has been interpreted.

The principal fault in the area mapped is the Stank fault which extends for a distance of about a mile in an almost north-south direction, cutting across the Stank Hill. The strata west of the Stank fault are inclined toward the east; east of the Stank fault of the operating mines the beds dip about 7° to the west. The faulting varies in width from about fifty feet at the Codd workings to twenty-five feet near the Springer workings and apparently disappears on the western boundary of the mapped area. Near the Springer ore body the fault is associated with a crush zone several hundred feet wide. In all of the limestone beds have apparently been broken into isolated segments. In spite of several dozen miles of surface and short tunnels dug into the hillside through the crush zone, no definite set of beds can be traced. The fragments thirty feet in length are apt to be terminated by the crush zone, and in places the segments themselves contain zones containing fragments of broken ore also.

Post-mineral faults cut all of the geologic units. Much local displacement took place after the Codd mass and before the present topography was developed. The lines are not reflected in the surface topography but are traceable by careful study of the limestone beds and the association encountered in the underground work.

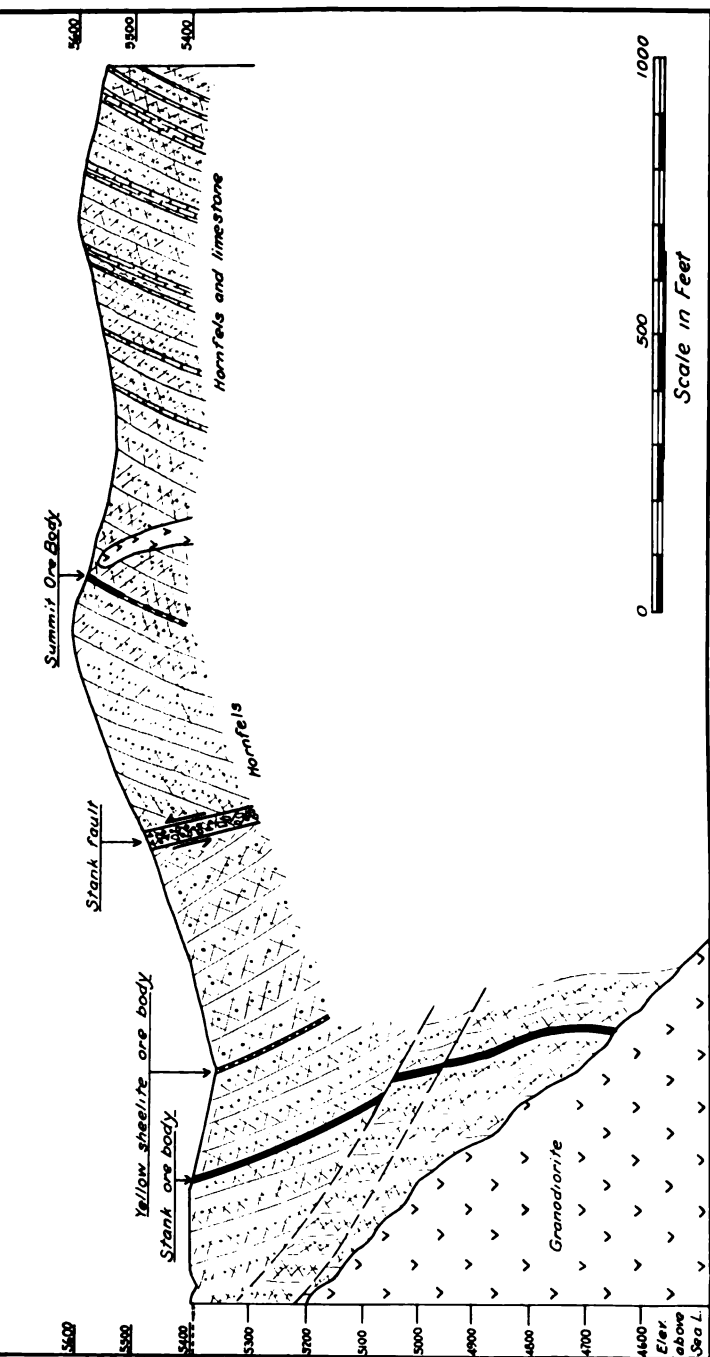


FIGURE 27. Cross-section of Stank Hill looking south. (See AA', Figure 7, also Figure 4.)

The post-mineral faulting just described is the principal structural disturbance of the area. Pre-mineral faults, however, occurred previous to the contact with the limestone beds. These faults are evidently older than the ore beds that occurred prior to metamorphism. The mineralizing solutions penetrating the country rock were completely recrystallized the gouge along the faults. The fault openings to such an extent that the usual mineral movement were obliterated. The pre-mineral faults are located by tracing the offset ore beds. Because of the difficulty in locating these faults and the sealed character of the planes, the pre-mineral faults cause the most serious problems in operations. Two pre-mineral faults that are indicated in Figures 28 and 29. One fault cuts the Humboldt ore body reaching the surface at the head of the tramway. The other cuts the Humboldt ore body north of the shaft.

DESCRIPTION OF INDIVIDUAL ORE BODIES

The three principal ore beds of the Tungsten district extend on an irregular N 20° E line for a distance of approximately a mile. This line is broken in a number of places, and the chief ore bodies now being worked may represent one continuous ore bed or may be composed of segments of two beds. In any event the replaced limestone strata have been broken by numerous faults, and have also been completely eliminated in places by the intrusive granodiorite. The faulting and the intrusion have produced gaps in the ore deposition which have rendered the problem of following the ore difficult. The two mines on the north are connected underground, but may be operated on two different beds, although development work has not proceeded to such an extent that this can be considered proven. A considerable offset exists at the junction between the Humboldt mine and the Springer mine, and the relation between the ore beds of the two mines has not been clearly established. The Stank mine farther south is isolated from the Springer mine, being separated by a considerable area of granodiorite (Figure 7). It is possible, however, that the replacement producing the ore in the three mines may have followed what was once the same limestone bed. Other metamorphosed strata exist in isolated segments roughly parallel to the main ore beds. These have not yet been thoroughly explored even at the surface, in spite of the fact that in many cases surface indications are quite promising and in several places scheelite ore can be found in outcrops. An abundance of ore reserves in the mines now working has made extensive exploration and development unnecessary in recent years.

The underground workings of the Humboldt, Springer and Stank mines present an interesting variety of geological problems of a decidedly practical nature. The distinction between the two generations of faults is particularly important since the pre-mineral faults have in general different criteria for detecting the direction of displacement than the post-mineral faults. The extent and intensity of the contact metamorphism appears important in governing the tenor of the ore. Zones of silicification must be followed since these zones appear to indicate the most intense metamorphism. The extent and depth of the igneous

intrusive is important, since when the intrusive mining will cease.

THE HUMBOLDT-SPRINGER ORE

The Humboldt-Springer workings are shown in plan view and a projected vertical section in Figure 1. The Humboldt mine extends underground for six levels, 600 feet below the collar of the shaft. The Springer mine, by means of a crosscut and a short raise with the Springer mine, and all operations from the Springer mine are now carried on through the Humboldt mine. The ore bed upon which the Humboldt mine has been developed is approximately 70° to the northwest, and strikes with a thickness throughout most of the workings 300 feet; in one place, however, where the higher levels are on the 300 level north it is fifteen feet. The ore is intersected by several fault zones and also by both granodioritic and andesite dikes. No ore is found in the dikes, but ore occurs on either side, however, even within a few inches of the margin of the dike. It appears that the late end stage solutions which followed the dike intrusions and the dikes themselves were the controlling factors in the distribution of the ore. In computing ore reserves, the dikes are measured as gaps in the ore body, and in mining operations as pillars.

Recent development work has exposed two new ore segments. One segment is shown in the plan view of the Humboldt 300 level south at the northern end of the workings, where the junction between the two ore beds is five feet in width, and averaging three feet in thickness. It has been exposed along a tunnel for approximately 100 feet. Whether this ore bed extends to the surface or how far it penetrates below the 300 foot level can only be determined by future exploration. It is a fair assumption that the new development represents a considerable addition to the reserves of the Humboldt-Springer mine.

The other recently discovered ore bed segment is at the north end of the 300 level north in the plan view. About three hundred feet of an ore bed fifteen feet thick has probably averaging between five and ten feet in thickness been exposed. The new ore body has also been exposed 100 feet beneath on the extreme northern end of the 300 level. Development work has not as yet been completed.

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new Humboldt ore body extends all the way to the surface and how far it penetrates below the 400 level will need to be established by future development. Also, the distance to granite on the north is unknown, although it is probably at least 700 feet horizontally, judging from surface exposures. The prospect of considerable extension of this ore body would appear to be unusually good from the geological standpoint. It is probable that at certain outcrops west of Humboldt Hill containing contact metamorphic minerals and scheelite represent the surface exposure of this bed. Since the main ore body in the Humboldt mine has been worked to the 600 level, it is probable that the newly discovered ore bed may extend at least to a similar depth. Additional pre-mineral faulting has been encountered in lower levels,¹³ however, and it is not likely that the ore body will be entirely worked out until additional data is secured for the solution of the fault system in the Humboldt mine.

The ore of the high grade stope on the 300 level north consists chiefly of coarsely crystalline masses of scheelite in a groundmass of fine quartz and epidote. Both garnet-epidote masses and garnet masses containing quartz and coarse scheelite are also occasionally encountered. The ore of this stope contains much more visible scheelite than is usual for the Humboldt mine as a whole. For the most part the scheelite is disseminated in fine specks through the contact metamorphic minerals. The ore in the lower and north end of the Humboldt mine contains fine black pyrite and is more finely granulated than in the upper levels, but it appears to contain as much scheelite.

As the mine has been deepened from level to level the operators have been in fear that the underlying mass of granodiorite might be encountered and the bottom of the mine would be reached. No bottom has as yet been encountered, however, and it is clear from the depth to which mining has been carried that the sedimentary cap on the granodiorite mass represents a pendant-like mass rather than a thin veneer as was supposed by the early operators who greatly underestimated the size of the deposit. No indication of the main granodiorite mass has been encountered in the lower levels, the granodiorite cut being the continuation of the same dikes or offshoots encountered at the surface. One granodiorite dike extends from the surface just south of the Humboldt shaft downward at an angle varying from 30° to vertical at the end of the 500 level south of the shaft. The same dike has been penetrated on each successive level as the mine was deepened.

¹³Encountered in development work since the original text was written.

A thin hornblende-andesite dike cuts the mine vertically on the north side of the Humboldt shaft. There is to be no information to be gained from the strike-slip, however, to indicate whether the bottom of the dike is a few feet or many feet below the 600 level.

As previously mentioned, the faults cutting the ore body are both pre-mineral and post-mineral. The pre-mineral faults appear to have caused an original displacement of the limestone before metamorphism took place; the post-mineral faults represent a more recent movement after metamorphism. The pre-mineral fault planes have been completely obliterated, all traces of gouge or fracture having been removed by the silification. It is only by careful study of the rock and a detailed inspection of the workings that the faults can be located by changes in mineralization. The post-mineral faults, however, were offset by such movement in places as much as a hundred feet.

The post-mineral faults are easily followed by the presence of indications of gouge and drag of ore fragments, and by the silification of the hornfels. The movements along the post-mineral faults appear to have been of less importance than the pre-mineral movements. The workers in the mine involved in following the ore body have had to make a location of faulted segments on the pre-mineral faults.

The operations in the Springer mine have been more restricted than the Humboldt mine, and mining has been done below the 300 level where the connection between the two mines occurs. On the south of the Springer mine a complicated post-mineral faulting has been encountered. An attempt has been made to drive tunnels south of the Springer gulch. The shaft of the Springer mine has a broad breccia zone of post-mineral faulting. The workings on the hill opposite disclose such a complicated faulting that isolated ore segments separated by faults that are not apparent appear to justify mining operations.

THE STANK ORE BODY

A geologic section cut at right angles to the strike of the ore bed is shown in Figure 27. This section follows the line of the map, Figure 7, and indicates the relative positions of the sedimentary strata on the two opposite sides of the Stank fault. One portion of the workings along the Summit fault crosses the Stank fault. The crosscut in this

STANK TUNGSTEN MINE
VERTICAL SECTION
MILL CITY, NEVADA

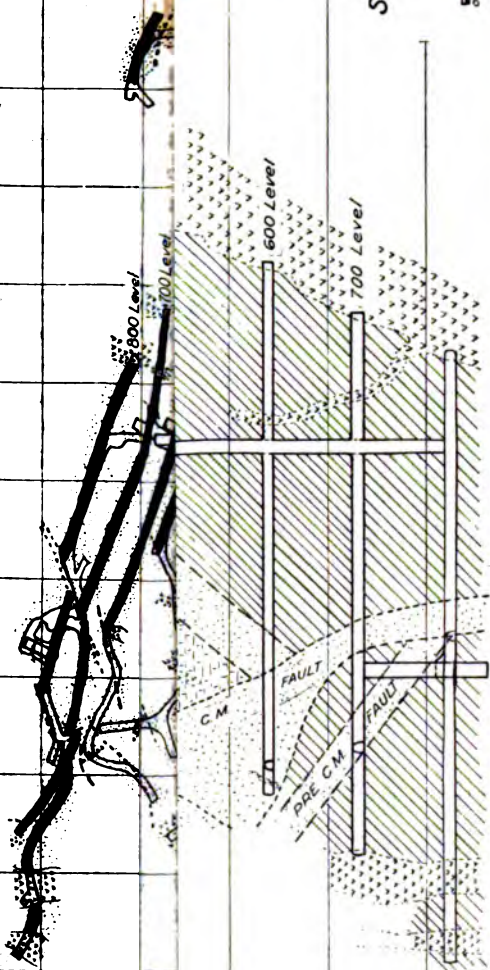


FIGURE 29. Plan and projected vertical section of the Stank mine.

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brecciation containing blocks of granodiorite, limestone, and shales. The blocks measure from a few inches to several feet in diameter, and are disarranged in a heterogeneous mass of brecciation. The Summit ore body, together with the adjacent hornfels and unreplaced limestone beds, appears to represent a block west of the Stank fault, while the Humboldt, Springer and other ore bodies, together with the adjacent granodiorite mass, represent another block east of the fault. The unreplaced limestone beds are shown in the section west of the Summit ore body.

These limestone beds present a problem of importance to the geology of the Mill City district. Adjacent exposures of ore demonstrate that the limestone, although unreplaced, is within the area of contact metamorphic action. The Summit ore body yielded some fairly good ore which was apparently cut off at the bottom by a pre-mineral fault, and the off-faulted segment has not yet been located.

West of the Stank fault is the Stank ore body and a small shale ore bed characterized by scheelite of a yellowish tint suitable for the name "yellow scheelite ore body." The Stank ore body has been opened to the 800 level with a dip varying from 70° to the west to vertical. In the lower levels, however, the dip is reversed and the ore body inclines at an angle of about 80° to the east.

The Stank ore body is shown in both plan and elevation in Figure 29. The best exposure of the contact between the granodiorite mass and the ore body may be found underground at the northern margin of the Stank workings. The contact has been exposed from the surface downward to the 800 level with several off-shoots penetrating a few hundred feet outwards and cutting the ore bed. The contact between the ore bed and the granodiorite is irregular, with numerous bench-like extensions of the igneous mass exposed along the open workings. The granodiorite has been removed for a vertical distance of eight hundred feet, leaving a narrow open stope eight or ten feet in width remaining, the hanging wall standing for the most part without support (Figure 9). All of the workings are not accessible, but in several places the granodiorite can be observed in contact with the shales of the adjacent hanging wall and foot wall of the ore body and in the lower part of the workings, where ore still remains, a sharp contact is visible. The scheelite in the ore extends to within a few inches of the granodiorite without any increase or loss of ore value. This is typical of the situation which appears to hold true throughout all of the contact areas

between the ore body and the intrusive in the

Several fair-sized blocks of unreplaced limestone are so poorly replaced that it would not compare with those encountered in the Stank workings. Like the underground limestone cavern about forty feet wide was penetrated. The cavern was formed by secondary leaching of unreplaced limestone at the south end of the Stank workings where the contact replaced and contact metamorphic action was

The same two generations of faulting are known in the mine that have been described in the Humbug workings. One prominent pre-mineral fault cuts the ore bed, extending from a point on the surface north of the Stank shaft underground to a point about two hundred feet south of the shaft.

There is no recent gouge or evidence of open faulting. On the other hand, slabs of rock broken from the fault later polished show the contact metamorphic quartzite on one side and quartzite on the other. The off-fault ore bed has been located on each successive level. The fault has been deepened and crosscuts were run in each direction, finding the ore body at the proper point. The position was established by geometric projection by the broken replaced segments being located during the course of the work.

In the lower levels of the Stank mine the pre-mineral fault is cut by a post-mineral fault, apparently having several branches. The movement on these faults appears to have been rotational, and the pre-mineral fault plane was rotated by motion on the south side of the post-mineral fault. The fault produced on the south side of the Stank mine is consequently somewhat complicated, and does not appear to have proceeded to such a point that the extent can be definitely established. A fair supply of unmined ore reserves exists in the lower levels at the end of the Stank mine, in spite of the faulting. It is hoped that future exploration conducted with care may yield worthwhile knowledge concerning the ore bed. The upper levels of the Stank mine are out, and the portion near the surface on the north is so poorly replaced and so badly broken that it does not appear to justify the expense of mining operations.

The lower levels will be called upon, then,

ring future operations along the beds now being worked. southward extension is possible in the lower levels and a considerable area of unexplored sedimentary rock exists between the present south end of the Stank mine and the Codd prospect. The same problem regarding the granodiorite floor beneath the sedimentary series exists in the Stank mine that has been discussed in connection with the Humboldt mine and the answer is equally uncertain. Operations have followed the replaced limestone bed in the Stank mine to a depth of over 800 feet, and indications of striking the underlying granodiorite are no more abundant than at the surface.

THE SUTTON BEDS

Mining operations were conducted during the early history of the district along the Sutton beds. These consist of two closely parallel limestone beds, about forty feet apart, nearly vertical in attitude, and exposed intermittently along a north-south line on either side of the town of Tungsten, for a total distance amounting to about 5,000 feet between the extreme north and south operations (Figure 2). The two beds may be traced by occasional exposures south from the southernmost operation for at least an additional mile. The east bed is normally from $2\frac{1}{2}$ feet to 5 feet thick, while the west bed varies from 2 feet to 4 feet in thickness. The Sutton beds are Upper Triassic in age, and furnish one of the few fossil horizons in the area. Hornfels occurs both between the two beds and on either side.

Exposures along the Sutton beds are intermittent due to hillslopes covered with soil and loose rock debris, areas of intrusive granodiorite and faulting which has displaced certain portions several hundred feet. The rounded hillslopes yield poor exposures, which make surface mapping difficult, and leave many gaps without reliable field evidence. Two large areas of intrusive granodiorite and a number of dikes cut the beds. One intrusive area on which the town of Tungsten is situated, eliminates approximately 2,000 feet of strata. East of Humboldt Hill is another large area of intrusive granodiorite which terminates the Sutton beds on the north. Faults almost at right angles to the strike of the sedimentary strata have offset portions of the Sutton beds for several hundred feet in a number of instances. Unfortunately, from the standpoint of mining, the beds have not only been offset but have been broken into numerous small isolated segments seldom exceeding 60 feet and frequently not more

than 20 feet in length. The faults are not and horizontal displacements, but include d as well, with the result that the broken blo are so irregularly distributed in the fault mining operations under present economic itable, even where the limestone blocks ha the formation of scheelite.

After eliminating the areas of intrusive extremely faulted portions of the Sutton 2,500 feet remain. This length is divided portion north of the town of Tungsten inc ton tunnel (shown on the hill just beyond T and the Baker prospect; the other portio including the South Sutton workings and ure 6). These two segments as exposed the underground workings are largely Portions, however, are said by the operator ore bodies, and in view of the history of th that the mineralization may increase with this increase can only be determined by f

HISTORY OF THE GEOLOGIC PROCESSES

The history of the geologic processes may be expressed in terms of a rather simple sequence of events. Between the period of Triassic deposition and the time the present topographic development began the important processes were metamorphism, igneous intrusion, and deformation. The periods of each process are indicated according to the following order:

- (1) Widespread metamorphism of the sediments throughout the district.
- (2) Deformation either before or accompanying igneous intrusion.
- (3) Igneous intrusion and accompanying contact metamorphism with end-stage alteration.
- (4) Later andesitic intrusion.
- (5) Post-intrusive deformation.

1. Evidence of the first alteration in the Triassic sediments is found in the limestone. A widespread metamorphism of the sediments must have taken place throughout the district, since abundant tremolite needles occur widely scattered through the gray limestone. Although the metamorphism produced tremolite, it did not destroy the carbonaceous matter in the limestone.

2. Following the early metamorphism, there was widespread fracturing of the tremolite crystals in the limestone and recementation by calcite. Mining operations also demonstrate displacement of the limestone strata at some stage between the early metamorphism and the formation of the ore beds. This may have occurred accompanying the early stages of the intrusion, although it probably happened before, since there is no evidence that the intrusive followed planes of faulting.

3. The igneous intrusion and accompanying contact metamorphism was responsible for the concentration of scheelite. The principal ore formation appears to have occurred toward the end of the intrusive action prior to the formation of quartz veins and accompanying end stage effects consisting of quartz-albite invasion and silicification. The processes of metamorphism appear to have been connected with the end-stage effects of the intrusion, starting with the quartz-albite phase and extending into the stage of silicification. As metamorphism progressed decarbonization of the limestone occurred, together with replacement of the tremolite and the development of two types of marble. The first type

of marble to be formed was a fine white marble. The green on the margins of unaltered blocks of green marble was later cut by a second marble. The green marble was essentially crystallized calcite due to more intense contact metamorphism. The coarse calcite was garnet, epidote, and scheelite. The coarse calcite was essentially crystallized in the order named. The green marble was formed during the periods of crystallization overlapped. It is general that garnet crystallized before epidote and scheelite. The chief ore forming period appeared to have overlapped and closely followed the end-stage of the intrusive. Following the garnet-epidote stage occurred a second epidote stage with extensive continued crystallization of scheelite. This was followed by the formation of actinolite and some tremolite. The contact metamorphism was concluded, and during the cooling zeolites were formed on the margins of the granodiorite mass and even within the ore bodies.

4. The hornblende-andesite appears to have formed after the cooling of the previous intrusive. It cuts all previously formed rocks in various directions.

5. The post-intrusive deformation appears to be chiefly in faulting. The faults of this general type cut all of the rock types associated with the intrusion and place the pre-mineral fault planes as well.

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J. R. KENNEDY, Editor

THE UNDERGROUND GEOLOGY OF THE TONOPAH MINING DISTRICT, NEVADA

By Thomas E. Dwyer,
Geologist, U. S. Geological Survey

Published by the Nevada State Bureau of Mines
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J. A. FULTON, *Director*

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UNDERGROUND GEOLOGY OF THE TONOPAH MINING DISTRICT, NEVADA

By T. B. NOLAN

INTRODUCTION

One of the projects undertaken as a part of the cooperative work done by the Nevada State Bureau of Mines and the United States Geological Survey during the biennium 1929-30 was a geologic resurvey of the Tonopah district, in Nye and Esmeralda Counties. In the summer of 1929 the mine workings in the western part of the district were examined, and during the following winter a preliminary report based upon the work was prepared.¹ The remaining mine workings to the east were studied in 1930. It was originally planned that the results of this second season's work would be incorporated in the final report on the district to be published by the Geological Survey. Unforeseen delays in the preparation of that report, however, have made it desirable to prepare the present report in order that the information obtained may become available to those interested in the district. Photostatic copies of the assembled mine maps of the district upon which the geologic information plotted have been placed on file in the Geological Survey offices at San Francisco and Salt Lake City and at the office of the Nevada State Bureau of Mines in Reno.

The preliminary report on the western part of the district is no longer available for distribution, the edition having become exhausted some time ago. A considerable part of the information in that report has therefore been embodied in this text. In addition certain general conclusions regarding the ore bodies in the district have been summarized here in advance of their presentation in the final report.

The writer desires again to express his appreciation of the many courtesies shown him by the mine operators of the district and his indebtedness to them for information regarding accessible workings. Ian Campbell continued as assistant in 1930 and freely made available the results of his microscopic study upon the rock specimens collected.² H. G. Ferguson and

¹Nolan, T. B., The underground geology of the western part of the Tonopah mining district, Nevada: Univ. Nevada Bull., vol. 24, No. 4, 1930.

²Campbell, Ian, The petrography of Tonopah, Nev. (unpublished thesis for degree of Ph.D., Harvard University).

G. F. Loughlin provided many helpful criticisms during their visits to Tonopah.

PREVIOUS GEOLOGIC WORK

The first detailed report on the geology of Tonopah is based on field work in 1902-3 for the U. S. Geological Survey made by J. E. Spurr.^{2a} He revisited the area between 1908 and 1915 and published two reports, one of which some of his earlier conclusions were revised. The following extract from the second of these reports summarizes his final conception of the geology:

At Tonopah the oldest rock is a trachyte containing quartz, sericite, and adularia. The lower part is a flow-banded glassy trachyte. The main body (the crystalline trachyte) contains the oldest and by far the most important mineral veins; the glassy trachyte appears to be younger.

Stresses subsequent to the trachyte extrusion resulted in fissuring near the zone of transition between the trachyte and its glassy lower portion; and along here (the trachyte and andesite) intrusion penetrated. After renewed stresses in the same zone, a glassy trachy-alaskitic intrusion, full of inclusions, took place, usually following the fissures above the andesite. Subsequent movement resulted in a new fissure, and a second trachy-alaskitic intrusion, a rhyolite sheet—which penetrated along a fissure immediately above the Montana breccia. At a subsequent eruption of andesite (Midway andesite) as a result of a later epoch there was a series of rhyolitic andesites and intrusions, of which the most important is a great intrusive mass called the "Tonopah rhyolite."

The principal veins were formed after the rhyolite, before the Sandgrass andesite-Montana breccia, and the intrusions. They are quartz veins carrying copper and silver. A second set of veins was formed after the West End andesite, before the Midway andesite eruption. This set is divided into four successive groups—A, large typically barren tungsten-bearing veins; C, mixed quartz and tungsten-bearing veins; D, productive veins like those of the trachyte. A third set of veins was formed after the Midway andesite intrusion. They are quartz veins carrying copper and silver.

All these veins formed at shallow depths, and are held to represent various stages of temperature. The first set of veins represent the normal shallow-seated type of trachyte eruption; the second—period B veins—

^{2a}Spurr, J. E., Geology of the Tonopah mining district, Nevada, U. S. Geological Survey, Professional Paper 42, 1905.

^{2b}Spurr, J. E., Report on the geology of the property of the Tonopah Mining Co., Tonopah, Nev., published by the company, Tonopah, Nev.: Econ. Geology, vol. 10, pp. 713-760.

abnormally intense shortly sustained temperature, following the trachy-alaskitic intrusion; the second-period D veins a subsequent briefly sustained stage of temperature more normal to shallow depths; the third-period a relatively high but briefly sustained temperature following the alaskitic (Tonopah rhyolite) intrusion. No vein formation followed the andesite eruption.

The history of faulting is long and complex; important movements have taken place at every stage of the geologic history. These movements accompanied and were due to the volcanic disturbances.

Somewhat earlier Burgess⁴ reached a radically different conclusion from that formed by Spurr as to the nature of the several formations disclosed by the mining operations. He considered that the different formations originated as surface flows or accumulations of volcanic material, thus questioning Spurr's conclusion that many of these rock masses are intrusive. Burgess also noted that many of the productive veins continue downward from the Mizpah trachyte into the West End rhyolite, and he implied, although he did not so state, that the mineralization in the two formations is contemporaneous.

The district has also been briefly discussed by Locke,⁵ who in general agreed with Burgess that the formations are present in their proper stratigraphic sequence. Locke also questioned the validity of Spurr's statement that the mineralization occurred in several epochs and noted that "There is no mineralogical distinction whatever to be made between many veins which, according to the hypothesis [Spurr's] should belong to different periods."⁶

The origin of the ore deposits was discussed in 1918 by Bastin and Laney.⁷ These authors did not concern themselves with either the stratigraphic sequence or the geologic structure of the district. With regard to the ores, however, they noted that "Mineralogic differences between veins of supposed different ages are commonly no greater than may be observed in different parts of one continuous vein. * * * Upon the sole basis of the mineral composition and texture of the primary ore there would be little reason for the impartial geologic observer to regard the principal productive veins as of more than one age."⁸

The results of the geologic work prior to 1929 may perhaps be

⁴Burgess, J. A., The geology of the producing part of the Tonopah mining district: *Econ. Geology*, vol. 4, pp. 681-712, 1909.

⁵Locke, Augustus, The geology of the Tonopah mining district: *Am. Inst. Min. Eng. Trans.*, vol. 43, pp. 157-166, 1912.

⁶Idem, p. 164.

⁷Bastin, E. S., and Laney, F. B., The genesis of the ores at Tonopah, Nevada: *U. S. Geol. Survey Prof. Paper* 104, 1918.

⁸Idem, p. 9.

briefly summarized as follows: The distal series of volcanic rocks, which are considered to be a large part intrusive sills and by Burgess and Spurr of surficial accumulation. All these observations are relatively flat-lying and the attitude of an individual bed are solely the result of which is attributed by Spurr to volcanic irregularities in the original formations. Spurr postulates several different interpretations, a view which is directly challenged and questioned by Burgess, and not supported by Burgess and Laney. Spurr, Burgess, and Locke all agree that the "Midway andesite" is later than the ore and acts as a capping to the ore.

In the preliminary report published in 1907 on the basis of the much more extensive exploration, presented several new interpretations of the sequence of rock formations was found to be different from that proposed by Spurr or by Burgess and Locke. The formation was named the "Tonopah formation" and consists of a series of interbedded rhyolitic flows, tuffaceous, and laminated silts. Dark lavas, identical with those described by Spurr as the Sandgrass andesite, were found in horizons interlayered with the Tonopah formation. A trachyte was found to overlies the Tonopah formation conformably, the contact between them is occupied by an intrusive sill of West End rhyolite, a pluglike mass that was considered to be younger than the West End rhyolite but younger than the other formations as the Extension breccia. Two post-ore formations are recognized — the Fraction breccia, or basal breccia, and rhyolite dikes similar to those of the Brougner dacite of Spurr. The post-ore formations of the older authors could not be distinguished from the accessible mine workings.

In place of the flat-lying series of formations described in the reports, it was found that the rock units are tilted to form a westward-dipping monocline. A structural feature appeared to be a complex fault named the "Tonopah fault" and whose cross-section was described as that of a recumbent fault, dipping upward. A throw of about 1,500 feet was

¹Nolan, T. B., *op. cit.*

It was also found that almost all the known ore bodies of the district had been localized either in the compound fault itself or in branches from it, and that there was no evidence in favor of more than one epoch of silver mineralization. It was also suggested that both wall-rock alteration and the geothermal gradient may have influenced ore deposition.

Ian Campbell in 1931 prepared a doctoral thesis on the petrography of the rocks collected by the writer and himself during 1929 and 1930. This thesis has been used in the preparation of the present paper.

SUMMARY OF THE TERTIARY GEOLOGIC HISTORY OF THE TONOPAH DISTRICT

The examination of the mine workings in the eastern half of the district yielded information that gives a much more complete picture of the geologic history of the district, so far as it bears upon the formation and distribution of the ore bodies, than was possible in 1930, when the earlier report was prepared. As no pre-Tertiary rocks are exposed within the district, this account of the geologic history is confined to the Tertiary stage of geologic time.

The rock formations that enclose the ore bodies are all believed to have been derived from an igneous center west of the mining district, probably not more than a few miles away. The oldest of these formations, the Tonopah formation, is an interbedded series of rhyolitic flows, volcanic breccias and tuffs, and water-laid sediments made up of volcanic debris. In the eastern part of the district the very coarse volcanic breccias found to the west are lacking, indicating a greater distance from the center of volcanic activity. During the period in which this formation was accumulating, dark andesitic lavas were erupted on at least two occasions, and these flows constitute the Sandgrass andesite.

After the accumulation of the Tonopah formation, another series of andesitic flows, long known as the "Mizpah trachyte," was erupted. In several places underground the basal flows of the Mizpah trachyte interfinger with the uppermost beds of the Tonopah formation. There is also at least one bed of volcanic breccia within the Mizpah trachyte some distance above the base of the formation.

The eruption of the andesitic lavas was followed by an epoch of minor intrusive activity. The earlier of the two intrusives recognized, the Extension breccia, was found only in the western half of the district. It was intruded as a tabular mass along the

contact of the Tonopah formation and the extended eastward only as far as the gr Mining Co. The other intrusive mass, t also follows the contact between the Tono Mizpah trachyte, but is distinctly more s sion breccia. Like the breccia, it pinche absent in a number of places in the Belm

The original nearly horizontal attitude has been greatly disturbed by widespread est movement is thought to have occur north-south faults of low easterly dip, w Halifax and Mizpah - Extension mines. named the "Halifax fault zone." Becau westerly dips in the footwall of the fault of the zone are believed to have been uplift The total amount of uplift is unknown bu several thousand feet.

Either contemporaneous with or slight activity along the Halifax fault zone, the Tonopah fault and its subsidiary branches The three major fractures composing the characteristics. Both in plan and in sec traces, being convex eastward in plan a section. The axes of curvature on all th east-west line and plunge eastward at a along each of the three branches appears 1,500 feet, and the formations on the ha relatively dropped. A natural assumption the curvature along these fractures as th this is disproved by the absence of comp the wall rocks. The fault is believed to result of forces similar to or perhaps eve that caused the movement along the Hali uplifted footwall segment was of much A possible cause of the uplift along both sion of a large body of igneous rock, t main mass of which would initiate mover zone, and the advance of a small protub that mass would result in the uplift repre fault. Many east-west faults of small t crests of the three major branches of the of them dip to the north, but several dip

Small faults are thought to have formed at about the same time as the major fractures.

The uplift represented by the Halifax and Tonopah faults is believed to have been succeeded by a period of settling or collapse. This readjustment took place along at least three sets of faults. Two of these, one striking northwest and the other northeast, appear to have been essentially contemporaneous. The northwesterly faults, represented by the Mizpah, Monarch-Pittsburg, and other faults, commonly have the larger throws and are more persistent, but some of the northeasterly faults, such as the Belmont, Tesuro, and Silver Top faults, have been traced underground for considerable distances. In the Montana-Tonopah and North Star mines, there is a notable and rather complex association of faults belonging to these two groups which is believed to be the result of a progressively greater northward uplift along the Halifax fault zone. The third group of faults, which strike north and dip west, are largely restricted to the western half of the district.

It is probable that the mineralization in the district was in a broad sense contemporaneous with the faulting. The earliest stage consisted in a wholesale albitization of the andesitic rocks, particularly, and in most of the district this alteration was so intense that the andesites were originally believed to have been disrupted as albitic rocks. Relatively unaltered blocks of the Mizpah trachyte, however, were found in the Halifax mine and show rather clearly that the albitization was a phase of the alteration. A second stage was less extensive and consisted in the introduction of a quartz-adularia-sericite mineral assemblage. In the ground of the Tonopah Mining Co. in the central part of the district, this stage reached a maximum and may well have been directly above the cupola that has been suggested as the cause of the local uplift along the Tonopah fault. Away from this central area, a chlorite-carbonate alteration is widespread, especially in the andesitic rocks.

All the faults, including the Tonopah and Halifax groups, are locally followed by quartz veins of considerable size but in many places of negligible silver or gold content. These quartz bodies have replaced the shattered walls of the faults. They are on the whole earlier than the introduction of the ore minerals. The ore shoots also follow the faults but are far less extensive in their distribution. Their limitation to faults or parts of faults with nearly east-west strike (the Tonopah

fault and its branches and some of the suggests that these fractures were open to the surface as a result of tensional forces which developed with the settling that followed the uplift.

Several features of the ore deposits are consistent with the conception that the local uplift which produced the fault resulted from the intrusion of an igneous cupola. The central location of the quartz-adularia-sericite alteration zone is suggestive. A second feature is the apparent restriction of the zone to a zone 600 to 1,000 feet in vertical thickness at its highest altitude in the vicinity of the mine. The zone is at progressively lower altitudes on the flanks. The ore zone is believed to represent the temperature zone in which the silver minerals could be deposited in concentration, and the symmetry of its upper part is consistent with the area of most intense alteration being centrally located. A further suggestion of a centrally located source is the regular decrease of the gold-silver ratio toward the apical region of the productive zone.

Erosion must have attacked the elevated area soon after the ore deposits were formed. The fragments from the older formations are abundant in the Fraction breccia, which is a local source for the ore bodies and their enclosing rocks. The lower member of the Esmeralda formation, of which the breccia is overlain by the upper member, composed of volcanic material is dominant, and by late erosion breccias. The veins on Mizpah Hill were exposed by erosion for a short time during the deposition of the Esmeralda formation but were soon covered by the upper part. Then followed renewed erosion along the Halifax fault zone, tilting the Esmeralda though at lower angles than the former. The beds were in turn beveled by erosion; and the rhyolite flows, known locally as the "Oddie rhyolite," covered them. Dikes of this type occur in several places underground, and one of them crosses the Halifax fault zone. Recent erosion has exposed the rhyolite and the underlying Esmeralda and has exposed silver-bearing veins a second time.

ROCK FORMATIONS

Of the seven formations recognized during the field work in 1909 and 1930, two are younger than the ore bodies; the remaining five form the wall rocks of the ore bodies. The following list, in which the youngest rocks are at the top, summarizes their relations:

Post-ore rhyolite: Dikes and lenticular masses intrusive into the other formations.

Fraction breccia member of Esmeralda formation: A volcanic breccia that unconformably overlies the ore bodies and their wall rocks.

West End rhyolite: Sills, as much as 600 feet thick, intrusive into all the older formations.

Extension breccia: Tabular intrusive mass. Found only in the western half of the district.

Mizpah trachyte: A series of surface flows, with minor volcanic breccias, at least 2,000 feet thick originally, but much of its thickness removed by erosion locally.

Sandgrass andesite: Dark lavas, interlayered with the Tonopah formation.

Tonopah formation: Interbedded volcanic tuffs, breccias, and flows, which are conformably overlain by the Mizpah trachyte. More than 1,000 feet thick.

Tonopah formation—The name "Tonopah formation" was proposed¹⁰ in the report on the western half of the district for the rocks originally described by Burgess¹¹ as the "Lower rhyolite." Spurr¹² considered the formation to be the intrusive equivalent of extrusive rocks now exposed on the surface and used the names "Tonopah rhyolite" and "Tonopah rhyolite-cite." These surface rocks, however, appear to be much younger than the Tonopah formation and are believed to be, in part at least, contemporaneous with the Esmeralda formation. The Tonopah formation includes rocks that have been mapped previously as "Glassy trachyte" and "Montana breccia," but it does not include all the exposures that have been so assigned by Spurr, Burgess, and others.

The most significant and extensive exposures of the formation are found in the western half of the district, notably in the

¹⁰Nolan, T. B., op. cit., p. 10.

¹¹Burgess, J. A., The geology of the producing part of the Tonopah mining district: Econ. Geology, vol. 4, p. 687, 1909.

¹²Spurr, J. E., Geology of the Tonopah mining district, Nevada: U. S. Geol. Survey Prof. Paper 42, p. 41, 1905; Ore deposition at Tonopah, Nev.: Econ. Geology, vol. 10, p. 745, 1915.

westerly workings on the 1,200-foot, 1,500-foot levels of the Tonopah Extension mine. The rocks are exposed, however, in the deeper workings of the mines, though in these extensive faulted areas alteration tend to mask the character of the formation. The 1,000-foot and 1,100-foot levels of the Queen shaft, the 700-foot level of the Silver Queen level of the Belmont, and the 1,155-foot level of the Mizpah Extension mine all provide fairly good exposure of the beds.

The most striking feature of the formation is composed of an interbedded sequence of volcanic tuffs of varying grain size, porphyritic flows, water-laid deposits of several kinds, and silts that closely resemble beds in the Eocene.

The rocks described by Burgess¹³ as belonging to this formation, and the exposures in the Extension workings add abundant proof of the character of the great bulk of these rocks. The character is apparent in many places, and numerous examples of obvious gradation from coarse-grained material at the top of a bed to fine-grained material at the bottom. On the surface well-developed ripple marks were observed. The fact that these rocks are interbedded with flows of Sandgrass andesite renders it probable that the bulk of the formation is a surface accumulation.

Strongly flow-banded rhyolites interbedded with the members of the formation are widespread. They have been distinguished by some of the geologists of the district as "Glassy trachyte." It was not possible to map this rock separately because of its interbedding in many places with tuff and breccia. The flow banding is locally marked.

In the eastern mines the volcanic rocks are in smaller fragments, and the rocks on the surface are more uniform in texture and composition. This is taken to indicate an increased distance from the vent at which the material was erupted.

Campbell has studied the rocks under the microscope and described the microscopic features of the formation as follows:¹⁴

¹³Burgess, J. A., op. cit., pp. 687-689.

¹⁴Campbell, I. W., op. cit., pp. 34-35.

The tuffs consist typically of small angular fragments of quartz, thoclase (both adularia and sanidine), albite, and, very rarely, microcline and microcline-micropertthite, in a fine-grained groundmass. Quartz is much the most abundant of the larger fragments. Ferro-magnesian minerals very likely were present, but the frequent occurrence of small flakes and shreds of chlorite is now the only indication of their former presence. Zircon and colorless apatite occur sparingly. A faint kaolinization is rather widespread, occurring over the groundmass and the feldspars.

The groundmass is exceedingly fine grained, and although now much silicified and in part also sericitized and kaolinized, it still suggests its original ash structure. In many specimens the peculiar and distinctive cusplike and trilobate structures ("Bogenstruktur") typical of rhyolitic tuffs can still be recognized in outline, although the originally glassy shards are now entirely devitrified or silicified. These are not usually apparent at first sight under the microscope, and often only with plane light and with the field slightly out of focus that the structures become recognizable. They stand out by virtue of the fact that in the general recrystallization coarser grains of quartz (or sericite, as the case may be) have replaced the shards, while the detrital paste which filled the interstices has produced a finer-grained secondary material. The contacts therefore show the outline of the former structures.

The breccias exhibit a more heterogeneous aggregation of material. In addition to the constituents found in the tuffs, a variety of rock fragments is found. These are generally rather severely altered (by kaolinization, sericitization, and chloritization), so that the original character is often in doubt. They seem to have been derived from rhyolitic and andesitic rocks, for the most part not definitely correlatable with any known in the district. In part, of course, the fragments are clearly from lower beds of the Tonopah formation itself.

Concerning the flow-banded rhyolites known locally as "Glassy trachyte," he writes:¹⁵

Fluidal texture is quite commonly seen. Phenocrysts are not common. Crystals of albite are found occasionally. They generally show a varying degree of sericitic and kaolinic alteration. More rarely chloritic pseudomorphs after biotite(?) are found. The matrix is always much altered. The glassy bands are formed of secondary quartz; while the white opaque material proves to be quartz with large amounts of kaolin and sericite. Pyrite is very commonly disseminated throughout the rock. In its distribution it seems to show little preference as regards the more or the less quartzose layers.

The bottom of the formation has not yet been exposed by the mining operations. In most places the upper limit of the formation is marked by the intrusive West End rhyolite, which separates it from the Mizpah trachyte. At a few localities in the southeastern part of the district, notably on the 1,100-foot level

¹⁵Idem, p. 44.

of the Rescue-Eula mine, the intrusive is in normal contact between the Tonopah and the Mizpah trachyte is exposed. Here, as on the Belmont and Midway mine, the two formations appear to overlap each other, beds of tuff or breccia alternating with thin layers of typical Mizpah trachyte. The volcanic breccia resembling beds in the Belmont is also found within the Mizpah trachyte and extends above its base throughout the Belmont.

The total thickness of the formation in the workings of the eastern half of the district is less than the 1,000 feet found to the west.

In the previous report it was considered that the age was of pre-Miocene but probably Tertiary. No direct evidence was obtained in the east. It seems probable, however, that the age of the Tonopah and Esmeralda formations may be determined by the pronounced angular unconformity between them. To suppose at first. The two formations are in many phases of their lithology, implying different conditions of deposition may have been in evidence. A discordance in dip between the beds appears to exist along the Halifax fault zone, and the available suggests that there was only a short interval of time between the faulting of the ore zone and the deposition of the Esmeralda formation. The Esmeralda beds must have been subject to the faulting was completed, and as the formation contains large boulders of these rocks, the probability that deposition of the Esmeralda formation is after the uplift. If this assumption is correct, the formation may be of middle Miocene or early Pliocene age.

Sandgrass andesite—The rocks below the Esmeralda andesite were originally considered by Nolan as a phase of the Mizpah trachyte and were called "calcitic phase of the earlier andesite." This name was soon abandoned and the name was local and was called "andesite."¹⁷ This abbreviated term was used in 1910, although he considered that the formation was an intrusive phase of the "Midway andesite."

¹⁷Nolan, T. B., op. cit., p. 13.

¹⁸Burgess, J. A., op. cit., p. 691.

¹⁹Spurr, J. E., report to Montana-Tonopah Co.,

Spurr proposed the name "Sandgrass andesite,"¹⁹ at the same time recognizing the lack of relationship of these rocks with any of the other formations, and this name has persisted since that time.

The formation is found in many of the mines in the district, and the most extensive and least altered exposures are in the western mines. The 960-foot level of the West End, the 1,540-foot and 1,880-foot levels of the Tonopah Extension, and the 1,000-foot and 1,140-foot levels of the Sand Grass provide the best information as to its character and relations. In the eastern mines the 1,250-foot level of the North Star and the 765-foot level of the Montana provide minor exposures, and others may be present on the 1,400- and 1,500-foot levels of the Belmont, but neither of these was accessible in 1929 or 1930.

On the basis of the work done in the western mines²⁰ the writer considered that the Sandgrass formation represented a series of volcanic flows interbedded with the Tonopah formation. Two and possibly three separate bodies, having a total thickness of about 500 feet, separated from one another by tuff breccia, were recognized in the Tonopah Extension mine. On the 960-foot level of the West End mine the formation contains flows of different composition and texture, including dense flows, breccias, and strikingly amygdaloidal andesites. In the relatively few exposures that could be examined in the eastern mines the rocks are rather badly altered and have yielded essentially no additional information regarding the relations or character of the formation, although the North Star occurrences are best explained as being interbedded with the adjacent rocks of the Tonopah formation. The comparative scarcity of exposures, however, suggests that the andesite is thinner in this direction. Occurrences similar to those in the Sand Grass mine, where the uniformity of the formation prompted the suggestion^{20a} that the rocks at that place might be intrusive, were found, and it seems probable that the uniformity there observed is due to the fact that the workings that cut the formation are nearly parallel to the general strike and thus expose only a single flow.

The boundaries of the formation in the Red Plume, Midway, Montana, and North Star mines are locally irregular, but in these localities crushing and rather intense alteration has tended to mask the true relations. It seems most probable that all these

Spurr, J. E., *Econ. Geology*, vol. 10, p. 729, 1915.

Nolan, T. B., *op. cit.*, pp. 14-15.

^aIdem, p. 14.

occurrences are the result of minor warping and fingered contacts between the Sandgrass and Mizpah formations, with which it is interbedded.

The formation is dominantly gray-green. The bulk of the unaltered rock is porphyritic, the phenocrysts being three or four millimeters in diameter. Much of this material in hand is chloritized. Portions of the Mizpah trachyte in the formation are difficult to distinguish in thin sections, as the rock fragments are of the porphyritic type and the chloritized material is microscopically to the altered groundmass of the amygdaloidal phases and the black, sparingly pyritic. Both can be readily recognized in the less altered formation, such as those on the lower level of the mine.

Campbell's notes upon the microscopic examination follow:

In the amygdaloidal facies of the formation is a groundmass of chlorite. The feldspar is of medium size and, though mostly altered to calcite originally. Ferromagnesian phenocrysts are rare. The amygdules show concentric filling of quartz. Pyrite is found as swarms of small crystals present in the amygdules.

The basaltic rock consists of about 30 percent crystals of calcic andesine in a typical basaltic mass material is made up of exceedingly small interstices between which are filled with a mixture of chlorite and calcite. Magnetite in small submicron but apatite is relatively rare. Pyrite and zircon are also present.

Specimens from the vicinity of the Sandgrass show a porphyritic texture of altered feldspar phenocrysts in a fine grained, altered groundmass. The feldspar is altered to epidote, zoisite, sericite, chlorite and quartz. Remnants indicate that their composition was originally hornblende and very probably completely altered to elongate prismatic forms. The "fuzzy" border of black iron oxides, the interstices consist of chlorite and quartz, with locally a small amount of apatite. The groundmass seems to have suffered less alteration. Outlines of small lathlike to tabular crystals of quartz can be distinguished. These are though there may be a little orthoclase and albite. Apatite is found all the alteration products mentioned and calcite the most abundant. Apatite is

rock, and all of it is the ordinary colorless variety. Zircon was noted. Pyrite occurs sparingly in rather irregular aggregates. As may be seen from these descriptions, most of the formation albite-rich, and the term "keratophyre" might well be applied to these rocks, although the name "Sandgrass andesite" is retained here because of its long use in the district. In the earlier report the albite was considered to be an original constituent, but the field work in 1930 in the eastern part of the district indicated that the albite in the Mizpah trachyte, which in many respects similar to the Sandgrass andesite, is rather certainly the result of alteration (page 21), and it seems probable that the same thing is true of the albite in this formation. Usually the Sandgrass andesite has also undergone a quartzitic-adularia alteration, like that observed much more widely in the Mizpah trachyte.

Mizpah trachyte—The rock of andesitic appearance first described by Spurr²¹ under the name "earlier andesite," as originally defined included also the Sandgrass andesite, and therefore in 1915 he renamed the formation the "Mizpah trachyte."²² This name is retained in the present report because of its long usage in the district, although the present survey has shown that the rock in almost all exposures is an albitized andesite or keratophyre, and not a trachyte. On the lower level of the Tonopah Extension mine the local name "Victor andesite" has been used by some geologists for the formation. In most of the mines in both the eastern and western parts of the district there are exposures of rocks that have been mapped by Spurr, Burgess, and others as "later andesite"²³ "Midway andesite"²⁴ and described by them as lying unconformably above the Mizpah trachyte and forming a "cap rock" to the veins. In the report on the western part of the district²⁵ it was stated that the rocks in many places assigned to the "Midway andesite" cannot be separated from the Mizpah trachyte by reason of any original differences in composition or texture, nor was this rock anywhere seen to cap any of the veins. In many exposures of the supposed "Midway andesite" extensive chloritization had considerably changed their appearance, but within such altered masses less altered facies were

Spurr, J. E., op. cit. (Prof. Paper 42), p. 31.

Spurr, J. E., op. cit. (Econ. Geology, vol. 10), p. 720.

Spurr, J. E., op. cit. (Prof. Paper 42), p. 33; Burgess, J. A., op. cit., p. 703.

Spurr, J. E., op. cit. (Econ. Geology, vol. 10), p. 743.

Nolan, T. B., op. cit., p. 16.

found to be of the same keratophyric nature as the un-
tionable Mizpah trachyte. All the numerous
supposed "Midway andesite" examined in 1930 led to a similar conclusion.

Two places may be cited where veins are
sidered to be terminated upward by the
andesite. These are the 270-foot level of the
sion mine and the 800-foot level of the Belmont
locality a stoped vein belonging to the Belmont
Extension and West End mines may be seen
320-foot intermediate level. The stope from
through at two places on the 270-foot level
the hanging wall of the vein is seen to
the level, but above this point it steepens and
more westerly of the two stopes a cave in
provides clear evidence of the upward displacement
fracture. The wall rock on the level is completely
altered, but a thin section from a less altered
into the altered material, is identical with the
pah trachyte below. Similarly, on the 800-foot
mont, the upward extension of the Belmont
into a zone of branching veins, only poorly
ore-bearing, though here the dip flattens
Although the rock on the walls of the mine
extension of this branching zone is shown
as "Midway andesite," no definite contact
and the Mizpah trachyte in the walls of the
tions, and no change in lithology can be recognized
indeed, subsequent to the mapping, a productive
found within the supposed barren "Midway

All the exposures of supposed "Midway andesite"
accessible at the time of this survey have shown
convincing evidence that the rock is identical with
trachyte, either by their field relations to the
trachyte or by petrographic examination of
tedly Mizpah trachyte or by petrographic examination
below. Averill,²⁶ however, has recorded an
andesitic rock overlying the Mizpah trachyte
to represent the unconformable overlap of the
ite." This exposure was not seen by the writer
well be that at shallow depths in certain

²⁶Averill, C. V., Tonopah geology: Eng. and Min.

is an overlying flow, related to the post-Esmeralda andes-
or latites of the Divide district,²⁷ although it is most
probable that this rock is of any great extent or of any
economic importance within the productive part of the Tonopah
district.

The Mizpah trachyte is widely distributed throughout the
district and makes up the bulk of the exposures in all the
places. Because of the supposed restriction of the ore-bearing
minerals to this formation, its limits have controlled exploration to
a considerable extent, and much energy and ingenuity have
been expended in the fruitless task of separating the formation
from rocks believed to be younger.

The formation differs widely in appearance from place to
place, but these variations are due in large part to alteration
and deformation. By far the most common lithologic variety is
grayish-green porphyry. The phenocrysts of feldspar are
most invariably dulled by alteration, are somewhat variable
in size and abundance, and are set in a dense matrix locally
stained with chlorite. Pyritization is common. Two other varieties
of rock are found locally in the formation. One of these
is a flow-banded rock, which is sparingly porphyritic; it is
present to a minor extent in a number of the mines. The other
is a fragmental rock, commonly a breccia but locally tuffaceous,
which is generally well bedded. It too is found in many of the
mines, and in the Belmont a bed of this material is sufficiently
extensive to be separately mapped. Some of these clastic rocks
are closely similar to beds in the Tonopah formation.

Each of these three varieties of rock has been subjected to at
least three kinds of alteration. The most widespread has been
albitization of the feldspars, which has been so nearly com-
plete throughout all but the extreme eastern end of the district
that in the earlier report on the western half of Tonopah the
albite was considered to be an original constituent of the rocks.
This was the earliest alteration of the formation, as the albite
has been replaced by minerals of the other types. The next
most widespread alteration was chloritization, which has affected
the formation to varying degrees everywhere except in the cen-
tral area near the claims of the Tonopah Mining Co. It was
most intense near faults, and the resulting dark green sheared
rock shows almost no resemblance to the original porphyry. The

²⁷Knopf, Adolph, *The Divide silver district, Nev.*: U. S. Geol. Survey Bull.
pp. 155-158, 1921.

chlorite is generally accompanied by calcite and pyrite. The third variety of alteration was found in the central area and consisted in the presence of sericite, and adularia. Locally replacement of primary minerals by these three minerals has been essential. The resultant hard, bleached rock is in striking contrast to the chloritized and the albitized phases of the original rock.

Campbell's notes on the microscopic features of the rock follow. They apply to the albitized rock and to the relatively slight later alteration:

In thin section the Mizpah trachyte shows prominent albite phenocrysts, set in a fine-grained aphyric groundmass composed principally of quartz. A little quartz in the groundmass may be primary, but it is difficult to distinguish from secondary quartz. In the interstices in the groundmass are scattered small shreds of magnetite. Ferromagnesian phenocrysts are very rare. Apatite, much of which is pleochroic, is relatively common rather scant. Magnetite or ilmenite may be present, but if so, it is now entirely altered to hematite.

Albite, as noted above, is the chief feldspar. Its composition is $Ab_{95}An_5$. The phenocrysts are tabular with typical polysynthetic twinning, except where they have been altered by alteration. Neither pericline nor carlsbad twinning is common. Zonal growths are almost unknown. Some phenocrysts are altered to a greater or lesser extent. Sericite was the most widespread type of alteration. Adularization occurred, and there has also been some calcitization, and chlorite. Any two or even three of these may be found on a single crystal. Alteration of the groundmass is difficult to estimate with accuracy. It seems to be more rapid than that of the phenocrysts, but along with the phenocrysts except that much-altered specimens are found. Some phenocrysts have gone entirely to sericite, but the groundmass of intergrown quartz and sericite, with some calcite. Even in specimens that appear to be unaltered. It is common to find veinlets and nests of quartz or quartz and calcite.

Similar features have been found during the study of sections of specimens from rocks mapped as "Midway andesite." Albite phenocrysts are common, as are also quartz-adularia veinlets; ilmenite and apatite crystals, identical with those in the Mizpah trachyte, are present. Koschmann² has shown that no distinction can be made between the concentrates from the "Midway andesite" and those from the "Mizpah andesite."

²Koschmann, A. H., unpublished thesis, University of California.

A thickness of at least 2,000 feet of the Mizpah trachyte is indicated by the relatively unfaulted hanging-wall exposures in the Sand Grass and Tonopah Extension mines. The top of the formation is not known, except where it is unconformably overlain by the Fraction breccia. The Mizpah trachyte conformably overlies the Tonopah formation and must therefore be slightly younger.

Extension breccia—The name "Extension breccia" has been used locally for an intrusive mass of breccia which occurs only in the northwestern part of the district and whose relations are best exposed in the Tonopah Extension mine. It is probable that in some of the geologic mapping by mine geologists this formation has been included either with the Tonopah formation or with the "Montana breccia." No additional information regarding it was obtained in the eastern mines, and the following description is taken from the earlier report:²⁹

On the lower levels of the Tonopah Extension mine the breccia is found in the footwall of the Murray and Merger veins. The exposure continues up to the 600-foot level, but the area of breccia present at each level steadily decreases upward, because of the fact that the top of the breccia mass is somewhat steeper than that of the vein. The Extension breccia is also found on the hanging wall of the common Murray and Merger veins in the lower levels of the Sand Grass and Merger mines but is by no means adequately outlined there because of the relative scarcity of mine workings.

The intrusive nature of the mass is clearly shown in only a few places, such as the 1,880-foot, 1,760-foot, 1,680-foot, and 950-foot levels of the Tonopah Extension and the 1,000-foot level of the Sand Grass, the relations in other localities being more or less masked by alteration near the veins. The intrusion appears to have been localized along an earlier fault, striking nearly east and dipping north, within the Tonopah formation. On the 1,140-foot level of the Sand Grass, for example, west of the main body of the intrusive, a narrow dike of the breccia is found in this fault zone, which here separates breccias and tuffs of the Tonopah formation from Sandgrass andesite. Still farther east on the 1,050-foot level from the Extension No. 1 shaft, however, the formation is absent from the fault zone. The actual contact of the intrusion is in many places difficult to locate exactly. Rock typical of the breccia passes gradually through a variety in which fragments of the unaltered rock predominate, then to one in which they are exclusively absent, and finally to shattered wall rock cemented by thin veinlets of the Extension breccia matrix.

The greater part of the intrusion is remarkably homogeneous in appearance, consisting of fragments of various rock types set in a characteristically reddish matrix containing rounded dark phenocrysts of quartz. The rock fragments included are largely of the Tonopah formation and less abundantly of the Sandgrass andesite and Mizpah

²⁹Nolan, T. B., op. cit., pp. 17-19.

the Tonopah Extension mine, where the main body occurs as a westward-dipping mass separating the Tonopah formation and the Mizpah trachyte. It thins notably to the northeast, east, and southeast, and at several places in these directions the mine workings show it to be absent—for example, on the 1,330-foot level of the Midway, the 1,300-foot level of the Belmont, the 1,200-foot level of the Halifax, the 1,100-foot level of the Buckeye, and the 500-foot level of the Gold Hill. There are in addition thinner and less continuous sills of the formation at other horizons. Many of these are within the Mizpah trachyte, as on the 800-foot level of the West End and on several of the Belmont levels; others are within the Tonopah formation, as in the deeper western workings of the Tonopah Extension.

The intrusive nature of the formation is shown by several features. The most convincing is the fact that it cuts through the Extension breccia, which is itself intrusive. At several places there are small apophyses into the Mizpah trachyte, and in some localities inclusions of that rock are found in the main body of the rhyolite, which lies stratigraphically beneath the Mizpah trachyte. In addition, the rhyolite shows a narrow chilled upper border wherever later alteration has not been so intense as to conceal it.

Except where intensely altered, the formation is readily recognized by reason of the characteristic dense greenish matrix, in which are set abundant angular fragments of white chalky rock. The included fragments vary greatly in number and size. In the western part of the district they normally make up about a third of the rock and are commonly a quarter of an inch or more in diameter, some of them as much as an inch. Although the Tonopah formation, especially the tuffaceous members, has evidently supplied the bulk of the fragments, minor contributions have been made by all the older rocks, and those from the Extension breccia are the least abundant. To the east the fragments are generally much smaller, being commonly less than a quarter of an inch in diameter, and are, locally at least, less abundant. At the contacts of the formation, besides the chilled border, there are in some of the western mines coarse breccias with inclusions a foot or more in diameter. Similar coarse breccias were noted on the 400-foot level of the Mac-Namara mine as bands within the formation. Wherever these variations in the number and size of inclusions are found together, there is no sharp contact between the two phases,

but rather a gradual blending over a distance. A faint flow banding was observed at some places near the borders of the intrusion and within it.

Campbell gives the following notes on the character of the formation:

In thin section the rock is seen to be a very fine-grained, fully holocrystalline rhyolite. Sparse phenocrysts of orthoclase are found in a matrix of feldspar (mostly quartz, much of which may be secondary).

The white inclusions so prominent in hand specimen are distinguishable with difficulty under the microscope. The "cherty" and associated rocks appear to have been altered for the inclusions, because textures seen in a thin section are entirely similar to those characteristic of parts of the formation.

The alteration of the rock was chiefly sericitic, with a considerable amount of silicification. Pyrite is widespread in this formation, and many of the pyrite veins are quartz or sericite. Quartz veinlets in the rhyolite occur frequently, and in many of these adularia is a common accessory. Sericite occurs in such veinlets more rarely.

The maximum thickness of the formation at the West End Extension and Tonopah 76 workings is at least 600 feet thick. From west to east there is a rather regular decrease to zero. The rhyolite intrudes all the formations previously mentioned, and they, in turn, unconformably overlain by the Fraction breccia.

Fraction breccia—This rock was first described by Spurr as the "Fraction dacite breccia." It was later called "fraction rhyolite breccia" by Knopf,³³ as a result of his work in the Divide district, south of Tonopah. The term "fraction breccia" was proposed in 1930,³⁴ because the basal portion of the member contains local fragments of andesitic-appearing debris, with the result that there has been considerable confusion as to the nature of the beds. They have, for example, been called "Midway andesite"; indeed, a "Midway andesite" cappings of veins that were later proved to be this basal portion of the Fraction breccia.

No additional information about the breccia is given in the eastern mines, and the following paragraphs are taken from the earlier report:³⁵

³³Spurr, J. E., op. cit. (Prof. Paper 42), p. 39.

³⁴Knopf, Adolph, op. cit., pp. 150-154.

³⁵Nolan, T. B., op. cit., p. 21.

*Idem, pp. 21-22.

The formation is exposed in the workings of the Jim Butler, Mac-Namara, West End, West End Extension, Monarch-Pittsburg, and Tonopah 76 mines as a generally southward-dipping mass that unconformably overlies the older formations and the veins. In detail the lower contact of the beds is very irregular, showing that the surface upon which they were deposited had moderate relief. In many places the major faults that affect the veins appear to have exerted a control upon this old surface, for the breccia extends deeper where such faults formerly reached the surface. In addition, relatively slight renewed movement along many of the faults has resulted in shearing of the breccia.

The formation as exposed underground is almost everywhere a massive rock without any indication of bedding, although in a few places interlaminated fine-grained material may be observed. Near its contact with the older rocks it is generally sheared, presumably as a result of the later earth movements that imposed upon the formation its general southward dip. The basal beds are commonly made up almost exclusively of rock fragments that are andesitic in appearance, although most of them are undoubtedly keratophyres derived from the Mizpah trachyte. The proportion of matrix in this variety is in many places relatively small, and for the most part the matrix has the same dark color as the fragments. Higher up in the formation the rock is lighter colored and has a lower ratio of fragments to matrix. Of this portion Mr. Campbell writes:

"The matrix is light colored, exceedingly fine-grained, and under the microscope appears holocrystalline to hypocrystalline. Fluidal texture has been observed. The aggregate index is lower than canada balsam and higher than gamma of sanidine. Phenocrysts of quartz and sanidine are abundant, and there are a few of albite and biotite. The sanidine is generally much altered to calcite, the albite somewhat altered to sericite, the biotite also to sericite. There has been some silicification throughout the rock and heavy kaolinization locally. Pyrite, partly altered to limonite, occurs sparingly."

Only a small part of the formation is exposed in the underground workings so far examined, and the determination of the total thickness must wait until the surface exposures have been adequately studied.

The Fraction breccia is considered by Ferguson³⁶ to be the basal member of the Esmeralda ("Siebert") formation and is assigned to the upper Miocene.

Post-ore rhyolite—Dikelike masses of rhyolite are the youngest rocks found in the mine workings. They are exposed in several places, but only three of the bodies are large enough to warrant specific mention. One of these is a thin dike which occurs on the 1,680-foot, 1,760-foot, and 1,880-foot levels of the Tonopah Extension mine near the Cash Boy shaft. It definitely cuts across the veins in at least one place and is unaffected by the mineralization, being therefore post-ore. A much larger dike is exposed

³⁶Ferguson, H. G., Geology and ore deposits of the Manhattan district, Nev.: U. S. Geol. Survey Bull. 723, pp. 42-43, 1924.

on the 800-foot level of the West End and Belmont mines, where it cuts the Fraction breccia and wall rocks. It does not come into contact with the Fraction veins, so far as known.

The third and largest body is a bulbous dike cut by the workings of the Belmont, Halifax, and Rescue-Eula mines. This dike localizes the Belmont vein on the east and the Halifax vein on the west, clearly later than the ore deposition. It crosses the Halifax fault zone, and like that zone has a low dip to the east. This dike appears to be a feeding channel from which was erupted the top of Mount Oddie.

In all these occurrences the rock is a light-colored, fine-grained rock with abundant quartz phenocrysts. At the 900-foot levels of the Belmont there are thin sections of the older wall rocks, and in places of the Fraction breccia, but thin sections of the Fraction breccia, as well as the continuity in depth, show that this is a near-surface phase of the Fraction.

Campbell's notes on the thin sections of the Fraction are as follows:

In thin section the quartz phenocrysts are generally rounded but locally are embayed. They are slightly fractured, and are rather fine-grained. Phenocrysts of sanidine are common, and in places show partial alteration to calcite. More rarely there is a small flake of biotite, now altered to chlorite. The groundmass has been much silicified, as is well shown where the secondary silicification has produced a quartz phenocryst, similar to the well-known quartz phenocrysts that occur typically in quartzites. If we consider the groundmass seems likely that this groundmass was holocrystalline, of quartz and orthoclase. There has been no alteration, and locally small patches of calcite occur.

In part, at least, these rhyolites are identical with the rhyolite as defined by Spurr,³⁷ but some of them are dacite, to his Brouncker dacite.³⁸ The surface rhyolite has been studied, but there appears to be little difference between them.

FAULTING

The older reports on the Tonopah district have considered several formations as being essentially

³⁷Spurr, J. E., op. cit. (Prof. Paper 42), p. 49.

³⁸Idem, p. 44.

³⁹Burgess, J. A., op. cit., fig. 87, p. 705. Locke, 1909. Spurr, J. E., op. cit. (Econ. Geology, vol. 10).

implied that the bulk of the major faulting was later than the deposition of ore.⁴⁰ In the report on the western part of the district⁴¹ evidence was presented to show that neither of these conclusions is valid, as the formations were found to be considerably tilted, and that their apparently horizontal attitude in the older central part of the district is the result of extensive premineral faulting.

The two block diagrams (plates 1 and 2, in pocket) show the principal structural features of the district and their relations to one another. Plate 1 was prepared for the earlier report and covers the western part of the district; plate 2, which is based on the exposures in the eastern mines, differs from plate 1 in that the region which it portrays has been split into three units, in order that more of the workings may be shown. In this plate the block is viewed from the northeast instead of from the northwest, as in plate 1.

The tilting of the rocks is shown chiefly by flow banding of the lavas and bedding planes of the sediments, and these correspond in attitude to unfaulted contacts projected from level to level in the mine workings. The dips are dominantly toward the west throughout the district, and in the extreme western part where there has been relatively little faulting, the westward dip is fairly uniform and averages about 45°. In the central and eastern parts, however, there is less uniformity, although the net result is a westward dip of approximately the same amount. In this more intensely faulted area individual dips either may be much steeper than 45°, as at many places in the Belmont mine, or much less than 45°, as in some workings from the Mizpah and Silver Top shaft. On the 700-foot and 800-foot levels of the Red Plume and the 700-foot level of the Mizpah there are low northerly and easterly dips. These caused the suggestion in the earlier report⁴² that there might be an anticlinal fold in the rocks in this vicinity, but the additional work in the eastern mines showed that this conclusion was wrong, and the easterly dips observed at these places are now considered to be due to the proximity of several major faults.

The movement along the faults must have been largely accomplished before the deposition of the ore, for essentially unshattered quartz has been deposited in places along almost all of them. In some of these occurrences such quartz is continuous with the quartz of the ore-bearing veins, and in several

⁴⁰Spurr, J. E., op. cit. (Econ. Geology, vol. 10), pp. 766-769. Burgess, J. A., op. cit., pp. 709-711.

⁴¹Nolan, T. B., op. cit., p. 23.

⁴²Idem, pp. 23-24.

places ore has been stoped from shoots that are on the Merton fault or vein in the Tonopah Extension, and Tonopah 76 mines, the MacNamara mine, the Mizpah fault in the Belmont properties, and branches of the the Halifax mine. There has been post-ore faulting in several places, as shown both by the presence of ore in fault gouge and by the faulting of younger rocks as the Fraction breccia and post-ore rhyolite. Movement appears to have been relatively slight.

The faults found underground may be divided into several groups, based upon their strikes and dips. Each of the three groups are believed to be of different age and to represent phases of a single epoch.

One group constitutes a fault zone of rather low east dip, which is restricted to the district. It has been called the "Halifax" fault zone, the Halifax mine, in which it is well exposed. There are several faults, which is probably younger than the movement along the Halifax zone, and subsidiary faults that branch from them at right angle strike and either northerly or southerly. The fault is compound and is unique in the district. The component faults have curved traces in both plan and section, convex eastward in plan and convex upward in section. All three of these component faults have the same nature that fall along the same east-west line and dip eastward at a low angle. Most of the ore mined in the district are localized along the main fault and its branches. The third group includes faults of steep and northwest strikes and also some faults of low west dip. The group as a whole is thought to be contemporaneous and to be younger than the other faults.

Halifax fault zone—The Halifax fault zone, which includes the Halifax, Mizpah Extension, Belmont, and MacNamara mines, consists of a linked group of slightly curved faults of general northerly strike and an eastward dip of 35° or 40° . Many of the workings in which the fault was exposed were not accessible in 1930; a cross-section, however, may be seen on the 1,100-foot level of the Belmont and the 1,155-foot level of the Mizpah Extension.

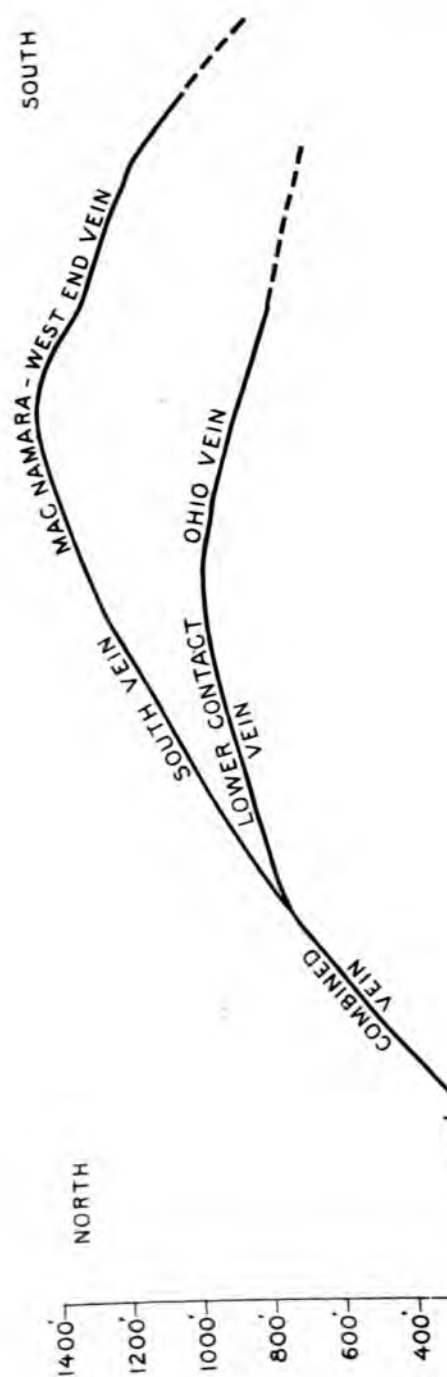
The fault zone has been of considerable economic interest, in that a member of it has terminated the Belmont vein eastward on the upper levels of the Belmont mine, and other members have cut the Halifax vein into several segments, only two of which are known to be ore-bearing. The difficulty of picking up the faulted vein segments is materially increased by the fact that post-ore rhyolite has been intruded along the fault zone, and some of the dikes are several hundred feet wide. In places there has been some mineralization along individual faults in the zone, and in a few of these places, such as the north end of the 1,100-foot level of the Halifax mine, small stopes have been opened. None of these workings appear to have been profitable.

The total amount of premineral movement along the Halifax fault zone is unknown but was probably more than 2,000 feet, to judge from the reported presence of Mizpah trachyte in the hanging wall of the most easterly branch on the 1,700-foot level of the Halifax mine. The throws of individual faults within the zone appear to vary greatly, but the accessible workings are too few to determine them accurately, especially in view of their branching habits. There has clearly also been some postmineral movement along the zone, as is shown by the tilting of the Fraction breccia and by the crushing of the rhyolite dikes. This movement is believed to have been somewhat less than 1,500 feet.

Tonopah fault and branches—The second group of faults includes a very large proportion of the fractures along which ore shoots have been found. The compound Tonopah fault is economically the most important one in the group, partly because of the ore bodies found along it but mainly because it has controlled the localization of the numerous ore-bearing minor fractures that branch from it.

The two lower segments of the Tonopah fault, each of which has the appearance in cross section of a recumbent crescent, convex upward, are exposed only in the western half of the district. Figure 1 shows the extent to which these branches have been exposed by the mine workings—for considerably more than 1,400 feet vertically on the north limb and for nearly 700 feet vertically on the south limb. Ore bodies along different parts of the fault have received different names, some of which are shown in the figure.

The northern junction of the lower branch with the upper branch is well exposed on the 500-foot level of the Tonopah Extension mine. This locality is not shown on plate 1, which



does, however, show the junction of the branches in cross section between the 600-foot and 660-foot levels of the Tonopah Extension, about 500 feet southwest of the Sand Grass shaft. The upper branch is apparently unmineralized at this point. The comparable junction to the south has not been found by mine workings, but the dips of the two branches indicates that it very probably exists. The crests of these two "anticlinal" branches both plunge to the east at low angles, ranging from 5° to 20° . The rather inadequate exposures of the crest of the lower branch suggests that it plunges at a lower angle than the upper.

The Stone Cabin fault, exposed in several workings in the vicinity of the Desert Queen shaft, is believed to be a third and higher branch of the Tonopah fault. It has a much greater radius of curvature in plan than the two lower faults and plunges more steeply to the east (about 30°); to the north it becomes nearly parallel with the branching Mizpah fault and cannot be confidently traced.

No ore shoots have been found along the Stone Cabin fault and consequently it has not been extensively explored. Its curvature, its alinement with the two lower branches, and the similarity of its relations have led to its assignment to this second group of faults, although the mine workings do not expose a junction with the other two branches.

The curved trace of the Tonopah fault suggests at once that it is simply a folded fault that originally had a uniform dip. This view is not tenable, however, because there is no similar folding in the formations adjacent to the fault—in fact, the strike of the wall rocks is rather uniformly at right angles to the axis of the crest of the fault.

The only mechanically probable direction of movement along the three branches of the fault appears to be a relative drop to the east, down the axis of the crest of the fault. As measured in this direction the contact of the Mizpah trachyte and the West End rhyolite has been shifted about 500 feet down the nose of the lower or Ohio vein branch, about 1,500 feet down the nose of the middle or MacNamara-West End vein branch, and about 1,000 feet down the nose of the upper or Stone Cabin branch—a total movement of about 3,000 feet. All these figures are approximate only, because of the numerous other faults that affect this contact in the region where the measurements must be made. On the lower levels of the Tonopah Extension mine, in the western part of the district, this same contact is shifted

horizontally about 1,500 feet by the north and its splits (which here represent the upper branches of the fault), and this figure of displacement was a few hundred feet less at the

The subsidiary related faults are most numerous in the western and eastern parts of the district at present. The only large one found at depth occurs at the junction of the Tonopah Extension and Sand Gap faults. It is generalized and is locally known as the "Merger" fault. At the junction with the main fault plunges southward, but the two diverge from each other westward. At the junction the displacement along the main fault is about one-half, the remainder being along the subsidiary branch or split has yet been found in the West End mine.

Most of the branch faults have a displacement of a few hundred feet or less—and an eastward extension is found chiefly above the crests of the main fault of the Tonopah fault in the Tonopah, Butler, Montana, and Midway mines. The Merger vein branch in that their lines of intersection with the main fault, where known, are nearly horizontal. The dip angle is in a vertical rather than a lateral direction. In all these faults that have been adequately exposed, the displacement decreases rapidly upward. The upward dying out is accompanied by the development of one or more subsidiary veins by a steepening in dip. This appears to be exceptional, as its dip decreases upward.

Two general types of these subsidiary faults are distinguished. One steeply dipping set includes the North vein; its probable extension to the west as the Belmont vein; the Belmont, Lillie Belle, and Belmont mine; the MacDonald and other veins; the mine, all with steep northerly dips, together with some other veins in Jim Butler group. The Queen shaft, with steep southerly dips, is rather low (30° to 40°) north dips, is represented by the View vein, and the Shaft and Favorite veins in the mine, and possibly by the Rescue vein in the mine. The Valley View and Favorite veins both dip into steeply dipping veins like those of the main fault. Branch faults are much more numerous

the crests of the Tonopah fault segments, and their close genetic relationship with that fault is therefore not beyond debate, especially as there is some evidence that at least part of the movement along them was later than that along the Tonopah fault. They are, however, cut and offset by all the members of the third group of faults, and it is believed that genetically they are best placed in this second set.

Other faults—Of the three varieties of faults in the third group, those with northwest strike and a northeast dip that is commonly about 40° have had the greatest effect upon subsequent mining operations in that they have offset the fractures that were later to become ore-bearing. Three of these faults have been developed for considerable distances underground. The most westerly one is exposed in the Tonopah Extension, West End Extension, and Tonopah 76 mines. It is locally mineralized, and the ore shoot in Extension ground has been called the "Merton vein." The horizontal shift of the contact between West End rhyolite and Mizpah trachyte along this fault amounts to about 1,000 feet, and as the contact in this region dips about 45° , the vertical movement along the fault was probably the same. On the Extension 1,540-foot level, southwest of the McKane shaft, the fault is made up of two major branches, which in places must be 200 feet apart. To the west, however, they appear to join. The workings on the 800-foot level of the West End Extension and Tonopah 76 do not show a similar branching, unless the two masses of quartz found in the workings south of the main crosscut represent the western junction of the branches.

The second fault has been named the "Monarch-Pittsburg fault,"⁴³ owing to its occurrence in the mine of that name, where it is apparently mineralized. It is also exposed on the 800-foot and 960-foot levels of the West End mine, where it cuts off the Ohio vein fissure, and on the lower levels of the Tonopah Extension, where it offsets the fissure followed by the Murray vein. The fault is essentially continuous between the exposures in the Extension and those in the Monarch-Pittsburg, but it is cut and displaced by two large faults in the region between the Monarch-Pittsburg and West End mines. The offset of the Murray vein in the Tonopah Extension mine indicates that the vertical movement along this fault must amount to about 1,000 feet. The Monarch-Pittsburg fault, like the parallel fault to the west, is compound—two major branches, which unite both

⁴³Nolan, T. B., op. cit., p. 28.

to the southeast and to the northwest, being westerly workings. In the Tonopah Extension is known as the "Denver fault."

The Mizpah fault is the third and being westerly faults. It has been explored at Midway, Montana, North Star, Tonopah, Rescue-Eula mines, where it cuts off the veins. Locally, eastward-striking portions of ore shoots that have been stoped and the Mizpah fault vein. The fault is actually in most places there are two or more parallel faults where the fault movement has occurred. The fault appears to increase both to the north and to the east. It is difficult to determine with accuracy the throw along the Mizpah fault zone, because of its branching habit but chiefly because of the large faults in its vicinity. In the Nevada Extension ground, for example, the northern extension fault joins with it; in the Belmont mine the Belmont fault is a complicating factor; and the southeasterly extension is close to the extension fault zone. From the position of the Mizpah trachyte on each side of the zone, with allowance for the effects of other faults, the movement along the Mizpah fault must be about 1,000 feet, or essentially the same as along the Denver type.

The northeasterly faults of the group are abundant but appear to have smaller throws than the westerly faults. Some of them show a northeasterly strike, the northeasterly trend swinging to the north. The dip is to the southeast or east. Individual faults of this strike show different trends. The northeasterly faults and the northerly faults lead to the conclusion that all three types are of the same age.

The Sand Grass fault is the farthest of this kind and is well exposed on the surface of the Sand Grass mine, where it cuts the 770-foot level of the Extension mine. Other faults are believed to be extensions of the Sand Grass fault on the 770-foot and 1,050-foot levels from the shaft, the 1,000-foot level of the Ohio, the

Monarch-Pittsburg, and the 800-foot level of the West End Extension-Tonopah 76. To the east the Tonopah fault is dropped more than 150 feet vertically by the Sand Grass fault, but on the 660-foot level of the Extension this displacement is distributed along several branches.

The Rainbow fault, named in the Extension mine, is best exposed about midway between the Extension No. 1 and Sand Grass shafts on the 600-foot levels. In most of these exposures the strike is nearly north, but southward toward the 600-foot level of the MacNamara mine the fault splits and the main branch assumes a northeasterly strike. The workings in the Ohio vein, particularly on the 555-foot level, show that this southeasterly branch is cut and offset by the Extension fault of the third group. The vertical movement along the fault is about 150 feet on the lower levels of the mines. On the upper levels the throw decreases and is divided between several branches; the movement along the main southwesterly branch was about 50 feet.

The MacNamara fault is found throughout the mine of that name, where it displaces the upper branch of the Tonopah fault, and is probably continuous westward with a similar fault that cuts the lower branch on the 800-foot level of the West End. Eastward it is found in the 500-foot and 600-foot levels of the Red Plume but appears to die out in the Midway and Montana mines. The vertical displacement along the fault is more than 200 feet in the western part of the Ohio 800-foot level, but is less than 50 feet on the 500-foot level of the Red Plume. To the west the MacNamara fault cuts and offsets the Rainbow, Monarch-Pittsburg, and Extension faults.

The Edwards fault was named and is best exposed in the West End mine, where its several branches are roughly parallel to the southern limb of the portion of the Tonopah fault known as the "West End vein." It is similar in many respects to the MacNamara fault, which it parallels. Along the plunging crest of the Tonopah fault on the 600-foot level of the Red Plume and Mizpah mines the dip of the Edwards fault flattens notably, being about 10° .

The two faults of this type in the Belmont mine both show a change in strike from northeast to north-south. The more westerly is the Favorite fault. The strike of this fault appears to curve from nearly north-south to northeast-southwest when traced to the south, but its extent and exact relations are somewhat obscure because it is near the Mizpah and Stone

Cabin faults. Both of these faults are about 100 feet in some places by the Favorable fault. It cannot be recognized as distinct, and is probably the Stone Cabin fault, at least locally.

The Belmont fault may be recognized at the Belmont and Rescue-Eula mines. The fault is nearly due north, but northward this changes to nearly due east, and the most northeasterly exposures, which show strikes of N. 60° E. The movement is about 600 feet, and there is some evidence of thicknesses of the West End rhyolite. Horizontal movement to the east has been indicated by vertical movement. Mine workings of the Belmont near the west end of the fault show the Belmont and Mizpah faults intersecting with or no offset, although the movement has been considerable. This relation implies that the faults were essentially contemporaneous.

Among the minor faults of northeastern Tonopah, the Top fault in the Tonopah Mining Co. and the Belmont fault have been most extensively exposed. Movement along both of them has been traced laterally for more than a mile.

Northeasterly and northwesterly strikes are unusually common in parts of the Belmont and Mizpah mines. The relations of the faults of this type are complex and here also seem to indicate the contemporaneity of the two kinds of faults.

Faults with north-south strike and westward movement are in the third group of faults. They are found in the eastern mines, but a few with only minor movement are exposed to the east. The most thorough exposure of this type is the Extension fault, which has a vertical range of the Tonopah rhyolite. It is also found in parts of the MacNamara mine. On the lower levels of the Extension mine the movement along the fault amounted to about 125 feet. On the upper levels it appears to have been somewhat less because of the development upward of the fault.

The most westerly of these faults is the Extension fault in the Extension and in the West End mines. It offsets the Merton vein at the 76 mines, where it offsets the Merton vein.

somewhat less than 100 feet. Another, which may be called the "McKane fault," is found near the McKane shaft, where it meets the Monarch-Pittsburg fault. The vertical movement along it is about 150 feet just above the 1,540-foot level but appears to decrease rapidly upward, amounting to about 50 feet in the Monarch-Pittsburg workings. These levels were not accessible, and it is not clear whether this decrease in throw is the result of branching upward, as in the Extension fault.

The fault to the east behaves somewhat differently. This fault, which is unnamed, is about halfway between the McKane and Extension faults and is exposed in the workings from the Extension No. 2 shaft and the Extension incline. The maximum displacement along the fault in this vicinity appears to have been close to the 1,260-foot level, where the Murray vein has been dropped on the hanging-wall side about 100 feet vertically. Below this level the fault passes into a flexure, as is shown by the curving hanging wall of the Murray vein on the 1,540-foot level. Above the 1,260-foot level the throw decreases, and on the 850-foot level it is comparatively insignificant. This fault appears to be represented to the south by a fault of similar strike and dip that is exposed in two places on the 800-foot level from the Ohio shaft. Here, however, the throw is considerably greater, as the offsetting of the Monarch-Pittsburg fault by it indicates a vertical drop of at least 200 feet.

The Buried fault, exposed in the western workings from the Tonopah and Silver Top shafts, is the most easterly of the larger faults of this type. It cuts the nose of the middle branch of the Tonopah fault and drops it to the west slightly more than 100 feet. The workings from the Wandering Boy shaft indicate that it frays out southward and upward, and, as it could not be recognized in the Midway mine, it must also die out southward.

The faults of this strike and dip are both offset by and themselves offset the northeasterly and northwesterly faults. Faults of all three groups are locally mineralized and are therefore earlier than the ore deposition.

Origin of the faulting—The observed characteristics and relations of the three groups of faults have led to the following theory concerning their origin:

After the accumulation of the volcanic flows, sills and pyroclastic rocks that constitute the pre-Esmeralda formations, the

present site of Tonopah was uplifted. It is not definitely known, but several features have been due to the introduction of a new fault. The earliest uplift took place along the fault, the rocks in the footwall of the zone being pushed up to their present westward dip. Certainly the upper boundary of the Tonopah formation was an early uplift was progressively greater to the west.

A less extensive uplift was accomplished by the compound Tonopah fault, during the formation of the footwalls of the three major branches was relative to those in the hanging walls. The uplift effected may have been due to a small intrusion from the hypothetical igneous mass mentioned in connection with the formation of the major faults. The fractures developed above the crests of the fault segments, possibly as a result of stretching of the blocks due to the increase in the volume of the footwall block.

The period of uplift, represented by the Tonopah fault groups, was succeeded by one of settling. The faults of the third group were formed during the movements along them reflect the readjustment of the settling. Their relations to one another and the three types of faults in the group were contemporaneous, and their distribution conforms to the settling from a progressively greater settling to the west. It is also probable, from the relations of the faults to certain of the minor fractures related to the settling, that the readjustment may also have occurred during the settling as well.

ORE BODIES

The mineralogy of the Tonopah ore bodies has been described by Eakle,⁴⁴ Burgess,⁴⁵ and Bastin and Laney,⁴⁶ and character of the silver-rich ore bodies has been described by Spurr⁴⁷ and by Bastin and Laney.⁴⁸

⁴⁴Eakle, A. S., The minerals of Tonopah, Nevada, *Geology Bull.*, vol. 7, pp. 1-20, 1912.

⁴⁵Burgess, J. A., The halogen salts of silver and copper, *Nev. Geol.*, vol. 6, pp. 13-21, 1911.

⁴⁶Bastin, E. S., and Laney, F. B., The genesis of the Tonopah ore, *U. S. Geol. Prof. Paper* 104, 1918.

⁴⁷Spurr, J. E., *op. cit.* (Prof. Paper 42), pp. 83-84.

⁴⁸Bastin, E. S., and Laney, F. B., *op. cit.*

The ore bodies are replacement veins that follow faults or fractures and commonly are without well-defined walls. According to Bastin and Laney,⁴⁹ "ore-cemented breccias, true crustification, comb structure, and other features characteristic of the filling of open spaces are rare or developed only on a small scale. Banding somewhat resembling true crustification, which is locally conspicuous, is possibly to be explained by diffusion during replacement."

The size of the ore shoots and the grade of the ore mined have varied within rather wide limits. As most of the veins are only assay walls, the price of silver and the methods and cost of mining and milling at the time of extraction have been determining factors as to what could be profitably mined. The Tonopah vein has been stoped for 1,500 feet along its strike on several levels, and stope widths of 40 feet were reached on several veins. On the other hand, trial stopes on some of the smaller veins are very small. The average grade of ore mined on the whole decreased as the district has grown older. In 1904 the average value per ton was more than \$100, but dropped to \$20 by 1911 and ranged around \$15 for many years thereafter. A further drop to \$10 occurred in 1930. In some cases considerable quantities of \$6 or \$7 ore has been mined. The total production, from 1901 through 1934, has been slightly less than \$150,000,000.

Electrum (probably selenium-bearing), argentite, polybasite, tennantite, pyrargyrite, and other silver and base-metal sulphides are found in the hypogene ore, with quartz, a fine-grained pinkish carbonate, and barite, together with altered wall rock, as the gangue. The greater part of the quartz appears to have been introduced earlier than the silver minerals; the carbonate, however, is believed to be essentially contemporaneous with them. Pyrargyrite, iodyrite, and embolite are reported by Burgess to have been abundant in the veins of the Tonopah Mining Co., and Bastin and Laney⁵⁰ report some local supergene sulphide enrichment, which, however, they consider "to have been quantitatively much less important than the hypogene mineralization."

The discussion on the following pages has been directed to the factors that are believed to have controlled the localization of the ore bodies, as the search for new ore bodies is the most

⁴⁹Idem, pp. 9-10.

⁵⁰Bastin, E. S., and Laney, F. B., op. cit., p. 10.

pressing problem now confronting the report⁵¹ it was suggested that the ore to those portions of the Tonopah fault faults of east-west strike that were open rich solutions were circulating and had facilitate precipitation and accumulation. It was also suggested that depth might the localization of the ore bodies, but t sidered adequately proved.

The additional field work in the east has required some revision of these con fault and its branches are still regarded location of individual ore shoots and in provided the channels along which the traveled, but it is now believed that loca faults, specifically the Belmont, Mizpah, Merton faults, also were effective in de the ore-bearing solutions. The require be open at the time of mineralization is been necessary for ore deposition. The i on the localization of ore shoots is als significant, but its relative importance exaggerated in the report of 1930. The conclusions bearing upon the distributio importance attributed to the depth fac ore bodies at Tonopah now appear to relatively thin zone or shell, which rea in the central part of the district. The aries of this shell, although locally irr faults and formation boundaries. Becar relations to a zone of intense alteration high point of the shell, it is thought t represent isotherms, or lines of equal ter at the time of mineralization, and that temperature interval within which ore place.

The extent of this shell or productive which has been prepared from maps of the district. The upper and lower bou indicated by contour lines, which are mately accurate but nevertheless show

⁵¹Nolan, T. B., op. cit., pp. 32-34.

ne-shaped productive zone. The block of ground thus closed has yielded all of the ore mined in the district except by minor quantities from such mines as the California-Tonopah and Buckeye.

The east-west elongation of the zone and the coincidence of the median line with the crests of the three major branches of the Tonopah fault suggest strongly that this fault played a very important part in localizing the ore. Individual ore shoots in the western half of the district are largely restricted to portions of the two lower branches of the fault, and in the eastern half to the subsidiary east-west fractures that are considered to be genetically related to it. There is, of course, a direct connection in time between the ore and the Tonopah fault, because there are many younger faults that are also mineralized. It would seem rather that when the silver mineralization occurred, the compressive forces resulting from the settling of the crust produced the third group of faults (page 40) were still in existence, and that the east-west Tonopah fault and its subsidiary fractures were parallel to the direction of these forces and were therefore capable of being open to the passage of mineralizing solutions. Younger faults with a parallel strike might not receive ore solutions, but those whose strike was more nearly normal to the direction of the compressive forces would remain closed.

Although the younger faults are only locally ore-bearing, some of the larger ones also appear in several places to have played an important part in guiding the passage of the ore solutions. Thus the Merton fault, in addition to itself being ore-bearing, seems probably to have been the source of the ore in the Berdona and parallel veins of the Tonopah Extension mine. The intersections of the Monarch-Pittsburg fault with the Tonopah fault coincide with large ore bodies, such as the Denver and Murray ore shoots in the Tonopah Extension mine and the large ore body on the Ohio vein in the West End mine. The hanging-wall regions of the Mizpah fault and the Belmont fault are both marked by an unusual concentration of ore shoots, which decrease in value and become unworkable away from the faults. The influence of these faults in localizing ore shoots is believed to have consisted in part in furnishing a channel for the ore solutions to follow, eventually depositing their contained silver, as with the Merton fault and portions of the Mizpah fault; and in part in deflecting or intercepting

the solutions from the main channels into new channels without, however, being mineralized. The Belmont, Monarch-Pittsburg, Mizpah fault appear to be examples of this. The Halifax fault zone also appears to have been effective as a barrier in preventing the flow of solutions eastward, to judge from the relative positions of the ore bodies in its hanging wall.

The Tonopah fault and its branches, however, are ore-bearing only in relatively small extent. The productive portions of the zone are included within the zone outlined by the contours shown in plate 2. The zone thus outlined is a relatively symmetrical, roughly rectangular surface cut across the mineralized faults and the several formations.

Deviations from the regular trends of the ore zone occur in several places. The most striking of these is a terrace extending westward from the West End Extension at an altitude of about 5,000 feet. A notable thinning of the productive zone is also to be due wholly to post-ore erosion, and a breccia is found at this altitude throughout the zone. A different type of deviation from the regular trend from the intersection of the productive zone with the faults of the third group. Thus the contours on the top of the zone in this region coincide with the presence of the Belmont, Monarch-Pittsburg, and Mizpah faults. The westerly trend of the contours near the Belmont and the Tonopah Mining Company mine is due to the presence of the Mizpah fault. The westward trend of the contours west of the Mizpah and Silverton faults is caused by the fault west of the Mizpah and Silverton faults; and the Monarch-Pittsburg fault has caused the deviation of the contours observed in the vicinity of the Tonopah Extension mine.

The lack of relationship between the ore zone and either the known extent of the ore zone or the formation contacts seems to show that these two features must have played a minor role in the localization of the ore shoots. A factor, which has controlled the depth

ve been the temperature limits within which the silver minerals were deposited in commercial quantities, and the upper and lower surfaces of the productive zone are thought to represent roughly the isothermal lines for the two limiting temperatures.

Two features of the geology appear to offer support to this view. One of these is the spatial distribution of the quartz-sericite-adularia and chlorite-carbonate types of alteration, and the other is the variation in the silver-gold ratio from place to place.

The quartz-sericite-adularia alteration was most intense in a relatively small area in the ground of the Tonopah Mining Co., coinciding almost exactly with the highest contours on the upper surface of the productive zone. Beyond this central area, the chlorite-carbonate alteration was the dominant type.

Similarly the ratio of silver to gold varies with respect to this central zone. Plate 3 shows this ratio for all the mines that have produced more than 100,000 ounces of silver. These show a range from about 85 parts of silver by weight to 1 part gold in the central area to more than 100 parts both to the east and to the west, reaching a maximum of 111.5 parts in the ore from the Emerald County portion of the Tonopah Extension mine. The correspondence between the ratios and the contours would be even closer if corrections were applied to two of the ratios shown on plate 3. That for the Tonopah Mining Co. (90.1) is unquestionably too high to represent the hypogene ore, for it includes the oxidized ore mined at the surface. This ore has been relatively enriched in silver, as is shown by the ratio of 151.2 obtained from lessees' ore, containing over 2,000,000 ounces of silver, mined in the early days. The ratio of 78.1 for the North Star mine, on the other hand, appears to be considerably too low. Lessees have mined nearly half of the ore produced by this mine and apparently have selectively extracted ore rich in gold; for the two years 1913-14, during which more than half of the total silver output was mined through operations on a moderately large scale, the ore had a silver-gold ratio of 93.3, which fits very nicely between the Montana ratio of 92.5 and the Belmont ratio of 95.3.

In addition to the influence of the Tonopah fault and other east-west branches and of the temperature factor in localizing the ore bodies, it would appear that local conditions were also effective. The most important of these is believed to have been

the necessity of the fractures being open solutions. There seems to be fair evidence that mineralization was in large part independent of the introduction of the bulk of the quartz in the quartz mineralization in places effective against the passage of the silver-rich solutions along the Tonopah fault within the product masses of quartz whose silver content is variable, and in other places, particularly along the branches of the Tonopah fault, there are veins of rather high grade in which quartz is abundant. Renewed movement along the fractures after quartz mineralization is thought to have taken place in the formation of an ore body.

In the earlier report⁵² the character of the fractures was emphasized as an important factor in determining the more brittle rocks being considered as favorable for ore deposition. It was recognized, however, that the formation, such as the Mizpah trachyte, was favorable or unfavorable, depending upon the degree of alteration had undergone. This feature is thus in part a function of the temperature factor, as there is a rough correlation between the distribution of types of alteration and the productive zone. It would appear, however, that in the eastern half of the district that the degree of alteration consequently the physical character of the rocks has an influence in determining the location of the ore bodies. Factors that have already been discussed.

The formation of the ore bodies may be summarized as follows: After the uplift and settling of the several groups of faults described on page 33, the circulating solutions that had their source in the central part of the district, presumably coming from the central igneous rock, caused the widespread albitization throughout the district and, in so doing, established a pattern in which the isotherms were convex toward the highest points in the same central area. The types of alteration occurred, characterized by the presence of sericite especially in the central area and carbonate in the outer regions, and these were accompanied by a widespread introduction of silica. The position, however, was largely confined to the central area.

⁵²Nolan, T. B., op. cit., pp. 33-34.

pecially those with an east-west trend. The silver-rich mineralization followed and appears to have been still more limited, some of the fractures that had earlier been filled with quartz apparently having been sealed to the later ore solutions. The silver mineralization, even more than the quartz introduction, appears to have been controlled by the major fractures, utilizing those with east-west trend as channels of entry and being dammed or deflected by those with a north-south strike. Furthermore, deposition of the silver was limited to a relatively narrow zone that is thought to correspond with isothermal surfaces affected by an igneous mass below. Only the veins in the highest central part of this zone were exposed to erosion, and these appear to have been relatively enriched in silver.

SUGGESTIONS FOR PROSPECTING

The recent increase in the price of silver has considerably revived mining activity in the Tonopah district, which has been expressed so far in an increase in the number of lessees working in several of the mines. A prolonged maintenance of the existing price, if mining costs do not show a parallel rise, or further increases in the price, may be expected to result in renewed prospecting operations by the mining companies themselves. It is hoped that the following notes may be useful both for the lessee type of operation, in which dead work must be kept at a minimum, and for the more elaborate prospecting campaigns that require company operations.

It is probably true that past exploration through both mine workings and drill holes has been sufficiently extensive over much of the district, especially the central part, to indicate that no large new veins will be found. Possibly, however, segments of known veins will be found to contain profitable ore shoots. Several such segments appear to have been unexplored and might be prospected at relatively small expense. One such segment is believed to occur on the 600-foot level from the Extension No. 1 shaft, where the Red Plume or Extension north vein has been unexplored on the hanging-wall or east side of the Rainbow fault, the drift having been driven on a hanging-wall branch of the vein. Similarly on the 400-foot level from the Mizpah shaft there appears to be a lack of correspondence between branches of the Mizpah vein on the two sides of an eastward-dipping fault 200 feet east of the shaft, suggesting that there may be unexplored segments of veins in this region. It is thought that close study of the mine maps will bring out similar possibilities. It is, of course, possible

that such segments of veins, if found, at a relatively low cost of exploration of the area, make it a worthwhile gamble for less than the cost of the work naturally should be confined to the production of the ore well be limited to the vicinity of the main fault, and obviously guided the ore solutions.

The success of the Tonopah Mining Company in drawing the silver and gold from the low-grade ore drawn from the caved area along the main fault at the 200-foot level would seem to justify a similar attempt at the walls of other parts of this vein, in the hope that a large body of low-grade ore could be developed, amenable to cheap large-scale mining and processing. Other veins in the mines of the West End, Tonopah Mining Co. properties have wall rocks that contain small silver-bearing veinlets, the region of which a vein appears to offer the best chances of developing and milling of very low grade ore.

Prospecting designed to discover hitherto unknown ore shoots will probably require considerable expenditures of time and money. The writer believes that ore bodies can be found only in those parts of the area that have been either unexplored or but partially explored. For all practical purposes this means working in the eastern or western parts of the district. The high costs due to the necessity of pumping water. Such prospecting also faces the same difficulties as the mineralization was less intense in these outcrops. In other words, that less silver was deposited per unit of area than in the central region. Exploration to the east or south of the developed area appears to be successful, because there appear to be favorable fractures in these regions in which ore was deposited.

The eastern extension of the productive area appears more favorable for prospecting than the western. The fault zone dips at a steeper angle than the main fault. The work in the Halifax and other eastern mines has led to the conclusion that it was only locally possible to penetrate this zone. The western extension of the fault zone offers more favorable possibilities. The Tonopah fault in the footwall of the M

never been found, owing to the presence of the post-ore action breccia in this region. The north limb of the fault carries the major ore bodies in the western workings of the Tonopah Extension mine, and the region in which this fault lies within the extension of the productive zone would seem worthy of careful prospecting, should the price of silver be maintained at a figure that would warrant the probably high costs of exploration and mining. The country immediately in the hanging wall of the Merton and similar large northwestern faults within the productive zone would also warrant exploration under these circumstances, as veins similar to the Esmeralda vein might be expected to occur there. In connection with exploration in the western part of the district, it is possible that the unsatisfactory results on the 1,880-foot level of the Tonopah Extension mine were due to the fact that the Denison and Merton veins, where they were cut, are probably very close to the lower limit of the productive zone; the trend of the topographic contours on plate 3 suggests that at this altitude ore shoots might be found farther west along the two veins.

A much more speculative possibility is the exploration of the region for a few miles north of Tonopah. The origin of the faults and the ore bodies as outlined in the preceding pages is thought to be connected with a localized uplift in the footwall of the Halifax fault zone. It seems logical to assume that in other places along the Halifax zone there may have been similar local uplifts, which may also have been mineralized. Unfortunately the region to the north, which for several reasons is believed to be the more favorable, is largely covered by younger rocks, so that direct surface examination for signs of local uplift and mineralization is not possible, and the large area involved would make the cost of adequate subsurface exploration, either by drilling or by shaft sinking, much too great. It is possible that detailed instrumental mapping of the few scattered outcrops of the pre-Esmeralda formations might give some suggestions as to favorable regions, which in turn could be explored by drilling.



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